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Syzygium nusatenggaraense (Myrtaceae), a new rainforest tree species with a calyptrate calyx from the Lesser Sunda Islands, Indonesia

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Abstract

A new rainforest tree species of the myrtle family (Myrtaceae), *Syzygium nusatenggaraense* Sunarti & Y.W.Low is described here based on two collections from the Lesser Sunda Islands. This species is superficially similar to *Syzygium arcanum* P.S.Ashton, a Bornean endemic tree species, but differs in a suite of morphological characters and geographic distribution. The new species is illustrated, and description is here given.

Satu spesies pohon hutan hujan baru dari suku jambu-jambuan atau Myrtaceae, *Syzygium nusatenggaraense* Sunarti & Y.W.Low diterbitkan disini berdasarkan kepada dua koleksi dari Kepulauan Nusa Tenggara. Spesies ini mirip dengan satu spesies pohon endemik Borneo *Syzygium arcanum* P.S.Ashton, tetapi berbeda dalam rangkaian karakter morfologi dan distribusi geografisnya. Spesies baru tersebut diilustrasikan dan deskripsi diberikan di sini.

Keywords: East Nusa Tenggara Province, Flores, Malesia, Sumbawa, taxonomy, Wallacea, West Nusa Tenggara Province

Introduction

The genus *Cleistocalyx* Blume was erected to accommodate two Old World myrtaceous taxa with calyptrate calyces, namely *Cleistocalyx nitidus* (Korth.) Blume and *Cleistocalyx nervosus* (Lour.) Blume (Blume, 1850). Later, a revision of the genus enumerated 21 taxa occurring from Bangladesh to South-eastern China, through Southeast Asia into northern Australia, New Caledonia and Fiji (Merrill and Perry, 1937). However, the genus was not recognised by subsequent workers (such as Henderson, 1949; Kochummen, 1978; Hyland, 1983) due to lack of corroborative evidence acquired from anatomical studies (Dadswell and Ingle, 1947; Ingle and Dadswell, 1953; Pike, 1956; Schmid, 1972). Results obtained from molecular phylogenetic analyses showed *Cleistocalyx* to be polyphyletic; members of the genus were found to have derived from multiple lineages across the *Syzygium* phylogeny (Harrington and Gadek, 2004; Biffin et al. 2006; Craven and Biffin, 2010; Vasconcelos et al. 2020; Low et al. 2021). In addition, molecular results supported uniting of the various segregate syzygioid genera such as *Acmena* DC., *Jambosa* Adans., *Piliocalyx* Brongn. & Gris, *Waterhousea*

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B.Hyland and *Cleistocalyx,* under a single genus, *Syzygium* P.Browne ex Gaertn. (Craven and Biffin, 2010; Maurin et al. 2021).

Syzygium is the largest tree genus in the world with over 1000 species enumerated (Beech et al. 2017). Naturally occurring *Syzygium* species are restricted to the Old World, extending from the African continent through to the Indian subcontinent, Southeast Asia, Australia and the Pacific islands, but the centre of its species diversity lies in Southeast Asia (Craven et al. 2006; Parnell et al. 2007; Govaerts et al. 2021), in the phytogeographical region defined as Malesia (van Steenis, 1950). The most well-known species of the genus is the clove tree, *Syzygium aromaticum* (L.) Merr. & L.M.Perry, highly prized for its dried flower buds widely used as a spice, flavour enhancer, preservative and in pharmacology (Ridley, 1912; Burkill, 1966; Batiha et al. 2020). Other notable members of the genus are *Syzygium aqueum* (Burm.f.) Alston, *S. cumini* (L.) Skeels, *S. jambos* (L.) Alston, *S. malaccense* (L.) Merr. & L.M.Perry and *S. samarangense* (Blume) Merr. & L.M.Perry, cultivated in the tropics worldwide for their small to large, juicy, edible fruits (Kochummen, 1978; Ashton, 2011). Due to its immense species diversity and apparent lack of salient morphological characters for species distinction, *Syzygium* is notorious for being a "taxonomically difficult" group and was neglected by botanists, even labelled as a "Cinderella" genus (Craven, 2001; Parnell et al. 2007; Craven and Biffin, 2010). This is reflected in the large number of unnamed specimens held in various regional herbaria (Parnell et al. 2007).

Sumbawa is the largest island amongst a chain of volcanic islands that forms the Lesser Sunda Islands. While sorting through herbarium material of Sumbawan *Syzygium* at Herbarium Bogoriense (BO), an unidentified *Syzygium* specimen (*Kostermans 18766*) with a calyptrate calyx terminating in a long rostrum was encountered. In attempting to identify this taxon, we examined all *Cleistocalyx* taxa enumerated in Merrill and Perry (1937) and concluded that *Kostermans 18766* is distinct from all *Cleistocalyx* taxa listed in their revision. The *World Checklist of Selected Plant Families* (WCSP) records 22 *Syzygium* species for the Lesser Sunda Islands (Govaerts et al. 2021). We proceeded to examine herbarium specimens of these 22 *Syzygium* taxa held at K, BO and SING (herbarium abbreviations follow Thiers 2021-continuously updated), as well as virtual herbarium collections of the Nationaal Herbarium Nederland (L) through the BioPortal Naturalis website (https://bioportal.naturalis.nl/?language=en) and type images at JSTOR Global Plants (https://plants.jstor.org), and established that *Kostermans 18766* is distinct from the 22 *Syzygium* taxa enumerated for Lesser Sunda Islands. A survey of all *Syzygium* taxa with calyptrate calyx described for Malesia further revealed that *Kostermans 18766* is superficially similar to a Bornean endemic, *Syzygium arcanum* P.S.Ashton (Ashton, 2006; Ashton 2011), but distinct based on a suite of morphological characters and geographical distribution. It is concluded that *Kostermans 18766* is an undescribed novelty and is named here as *Syzygium nusatenggaraense* Sunarti & Y.W.Low. Separately, a collection from Flores (*Verheijen 3005*) that also represents *Syzygium nusatenggaraense* was brought to our attention by Peter Wilson (pers. comm.) and this extends the range of its distribution beyond Sumbawa.

Syzygium nusatenggaraense has a disjunct distribution represented by two collections across the Lesser Sunda Islands. Both islands, Flores and Sumbawa, have been relatively well botanised in the intervening years and the species has not been recollected, suggesting that it is rare. Although description of new species based on only two collections is not ideal, it is important to document biodiversity while species and their habitats are extant. This maximises their subsequent chance for rediscovery and further study.

Taxonomic treatment

Syzygium nusatenggaraense Sunarti & Y.W.Low, **sp. nov.** (Fig. 1).

Diagnosis: This species is morphologically similar to *Syzygium arcanum* P.S.Ashton but differs in having young twigs smooth and slightly compressed (vs angular and sharply 4-ribbed in *S. arcanum*), the leaf base obtuse (vs narrowly cuneate in *S. arcanum*), up to 30 pairs of secondary veins with spaces in between veins c. 1 mm wide (vs up to 10 pairs and 6–7 mm wide in *S. arcanum*), lower leaf surface sparsely black dotted (vs densely black dotted in *S. arcanum*), and flower buds obovoid with an abrupt pointed rostrum to 3 mm long (vs ovoid and without a conspicuous rostrum in *S. arcanum*).

Type: INDONESIA: West Nusa Tenggara Province: Sumbawa, West Sumbawa, Mount Batulanteh, northwestern slope, moist *Dipterocarpus retusus* forest, 500–700 m asl, 7 May 1961, *Kostermans 18766* (holo: L [L.2520634]! iso: A, BO [BO1721103]!, G, K!, SING [SING0212723]!).

Etymology: The species epithet denotes the fact that the species is so far known only from Lesser Sunda Islands, where it was collected from Flores and Sumbawa.

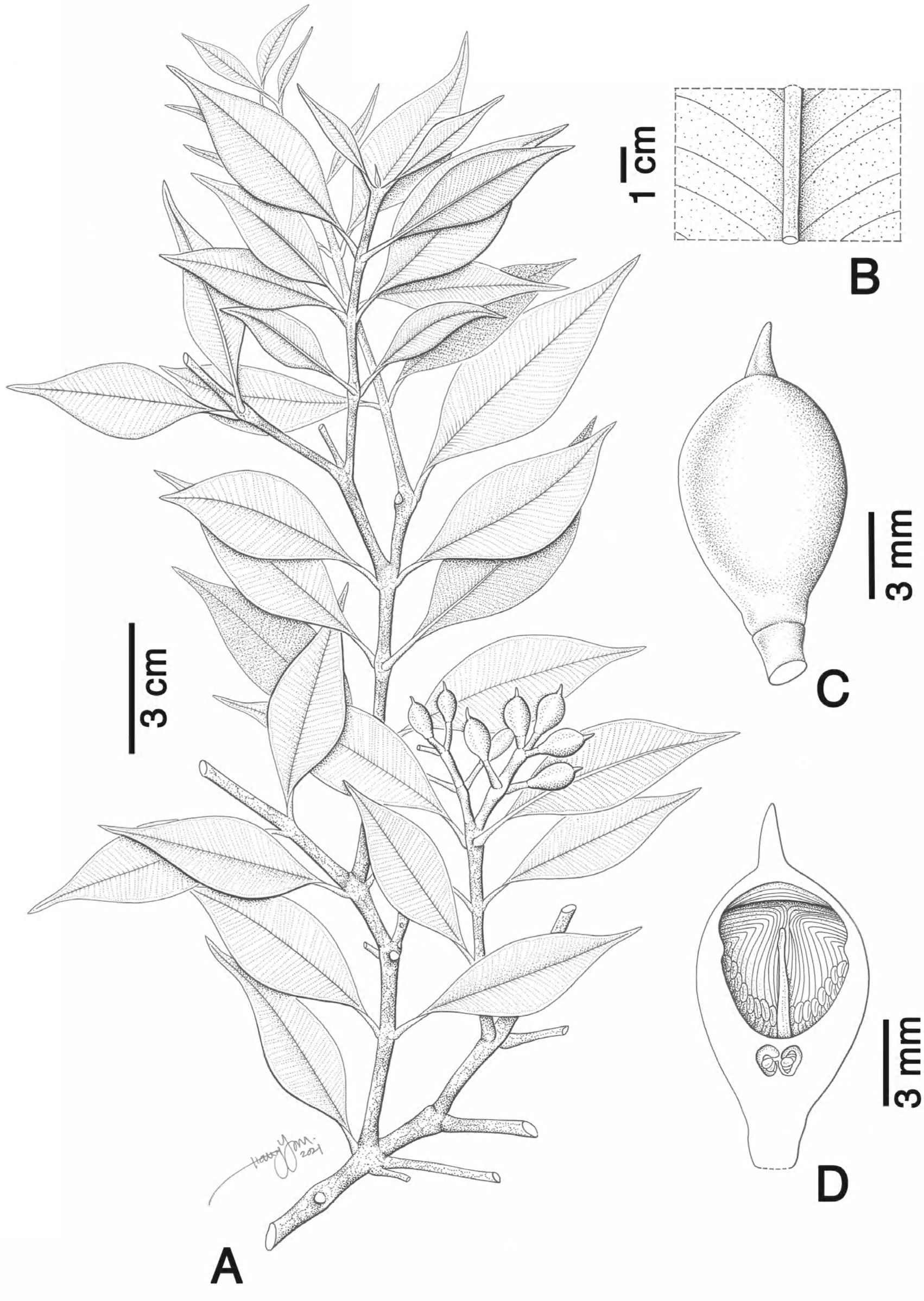

Fig. 1. *Syzygium nusatenggaraense* Sunarti & Y.W.Low. **A.** habit of a leafy flowering branch; **B.** close-up of lower leaf surface showing densely black dotted glands; **C.** close-up of a flower bud showing the apex terminating with a pointed rostrum; **D.** flower bud opened longitudinally; note the densely packed and folded stamens surrounding the immature style. All drawn from the type, *Kostermans 18766* (SING). Illustration by X.Y. Loh.

Tree to 25 m tall, 30 cm diam.; bark pale brown to dark brown, fibrous. Plants glabrous throughout. *Branchlets* smooth and slightly compressed. *Leaves* opposite to rarely subopposite and decussate; petioles 5–8 mm long, c. 1 mm wide; lamina lanceolate, 4–6 × 1.7–2.4 cm, thin coriaceous, drying dark brown, paler beneath, lower surface densely black dotted, margin entire; leaf base obtuse; leaf apex acuminate to caudate; mibrib sunken on upper surface, raised and prominent on lower surface; secondary veins numerous, up to 30 pairs, parallel and c. 1 mm apart, raised on both surfaces and more prominent on lower surface; intramarginal vein 1, up to 0.5 mm from the margin. *Inflorescences* terminal or axillary, up to 6 cm long, hardly branched or multiple

branchlets emerging from single node. *Flower* buds with a fused perianth (calyx lobes) forming a calyptra terminating with an abrupt pointed rostrum to 3 mm long, the calyptra falls off as a cap-like structure during anthesis, obovoid, 11–13 × 5.5–6 mm, pseudostalk to 2 mm long; pedicels 1–17.5 mm long; hypanthium obconical, 8–9 × 5.5–8 mm. *Stamens* numerous, arranged in rows at mouth margin of the hypanthium; filaments 5–8 mm long, dark red; anthers to 0.5 × 0.4 mm. *Style* to 9 mm long; ovary 2-locular, up to 11 ovules per locule; placentas axile, ovules radiating, ascending. *Fruits* unknown.

Distribution: *Syzygium nusatenggaraense* is so far recorded only from Flores and Sumbawa, Lesser Sunda Islands (Fig. 2).

Fig. 2. Geographic distribution of *Syzygium arcanum* and *Syzygium nusatenggaraense*.

Habitat and ecology: In Flores, *Syzygium nusatenggaraense* was recorded from the highlands of Potjo Gurung, Ruteng at 1700 m asl (Verheijen 1963; Mees 2006); in Sumbawa, it was recorded from moist evergreen forest dominated by *Dipterocarpus retusus* (Dipterocarpaceae) at 500–700 m asl.

Phenology: Flower buds, open flowers and immature fruits collected in May and September.

Preliminary conservation assessment: *Syzygium nusatenggaraense* is here classified as Data Deficient (DD), following the recommendations proposed under IUCN (2012). This species is known only from two collections made between 1961–1971 and more efforts are needed to document this species carefully in its habitat and to reassess its range, population size and threats considering almost all tropical rainforest regions have been identified as biodiversity hotspots (Myers et al. 2000; Nic Lughadha et al. 2020).

Additional specimen examined: INDONESIA: East Nusa Tenggara Province: Flores, Sano, Ruteng, Potjo Gurung, 1700 m asl, 18 Sep 1971, *Verheijen 3005* (L [L.2520595]!).

Notes: Phylogenetic studies (see Harrington and Gadek, 2004; Biffin et al. 2006; Low et al. 2021) have shown *Syzygium* species with calycine calyptra derive from multiple lineages and anatomical analysis (Vasconcelos et al. 2020) indicates that closed *Syzygium* calyces have multiple developmental origins. As a result, locating the species most closely related to *Syzygium nusatenggaraense* will be a challenge, further compounded by the lack of a complete inventory of *Syzygium* species occurring in the Lesser Sunda Islands and surrounding regions. It is possible that closely related species of *Syzygium nusatenggaraense* have free calyx lobes, but we are unable to identify plausible candidates amongst the 22 *Syzygium* species enumerated for the Lesser Sunda Islands until now (Govaerts et al. 2021).

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Seeds and indehiscent fruit of Anarthriaceae and Australian Restionaceae (Poales): a gallery of micromorphology

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Abstract

The diaspores of Anarthriaceae and Australian Restionaceae are seeds or small nuts and are illustrated by scanning electron microscopy or multi-focus microscopy. Their morphology is considered in relation to a previously published phylogeny based on plastid genes. Loculicidal trilocular capsular fruits are the basal condition in the restiid clade, but indehiscent fruits have evolved many times. In the Australasian members, indehiscent fruits are found in Anarthriaceae (*Hopkinsia*); Restionaceae: Centrolepidoideae (*Aphelia*); Sporadanthoideae (*Calorophus*); Leptocarpoideae (*Empodisma*, *Winifredia* and the whole of the *Leptocarpus* and *Desmocladus* clades). Seeds of dehiscent fruits show a diversity of surface ornamentation with distinctive surface patterns characterising genera such as *Lyginia*, *Chordifex* and *Loxocarya*. Pericarps are membranous in subfam. Centrolepidoideae, but in the *Leptocarpus* clade range from hyaline in much of *Leptocarpus*, to hard and woody in *Alexgeorgea* and *Hypolaena*. Pericarps are parenchymatous in most of the *Desmocladus* clade, but woody in *Catacolea*. Indehiscent fruits are mostly shed with tepals and floral bracts attached or, in *Baloskion* and some *Lepidobolus* species, also with the subtending glume. Seed weights were not comprehensively sampled but vary from 0.08 mg in *Centrolepis* to >600 mg in *Alexgeorgea*, with most in the range 0.3–3 mg [dry weight]. The smaller weights are mostly either in perennials from habitats with more reliable rainfall or in ephemeral annuals that avoid drought by their brief growing season, but the association between seed type and habitat has not been investigated. We see no convincing evidence to link the fossil taxon *Restiocarpum* and the *Milfordia* pollen that occurs with it in Eocene–Oligocene sediments of Queensland to Restionaceae.

Introduction

With leaves mostly reduced to sheaths and small wind-pollinated flowers, Anarthriaceae and Restionaceae seem to offer limited informative morphological characters to assist in characterising taxa. Culm anatomy offers a wealth of features, with major differences especially in the epidermis, chlorenchyma and presence of silica bodies (Cutler 1969, Linder 2000, Linder *et al.* 1998, Meney and Pate 1999b, Pate and Delfs 1999). Another source of distinctive features is the surface ornamentation of seeds, as we illustrate here for Anarthriaceae and for the Australian subfamilies of Restionaceae: Centrolepidoideae, Sporadanthoideae and Leptocarpoideae. The remaining subfamily, the African Restionoideae, was studied by Linder (1984) who found 'a great range in the surface micro-morphology of the seeds'.

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A phylogeny of the restiid clade of Poales (Fig. 1, derived from Briggs *et al.* 2014) provides a framework for this study and shows the clades that we refer to here. That phylogeny is based on analyses of several chloroplast genes and has led to some relatively recent changes in the generic classification (Briggs 2014a, b, Briggs *et al.* 2020a, b, 2020–2021). Anarthriaceae is recognised here at family rank as the sister group to the Restionaceae (Briggs *et al.* 2014). The latest Angiosperm Phylogeny Group classification, APG IV (2016), took a different view, including Anarthriaceae in Restionaceae. Hochbach *et al.* (2018) gave no phylogenetic support for or against including the *Anarthria* clade in Restionaceae but Givnish *et al.* (2018) advocated recognising Anarthriaceae sister to Restionaceae.

Materials and methods

This study proceeded intermittently over a considerable time, so the technology conveniently available to us changed over time. Most of the study used SEM with the following procedure: whole mature seeds were extracted from dried herbarium sheets. Seeds were readily extracted from fruit with membranous or parenchymatous pericarp, but with more difficulty from fruits with a woody pericarp. Standard SEM pin stub mounts, 12.7 mm surface diameter (product number G040 ProSciTech, Thuringowa, Qld. Australia), were used and self-adhesive sticky tabs (P/N IA022 ProSciTech) applied to the surface of the stub. The paper backing was peeled off before seeds were placed onto the adhesive tape. Prepared mounted stubs were coated in an EmiTech K550X sputter coater, using an energised gold target in an argon atmosphere. Default settings were used with a coating time of 3 minutes resulting in a gold layer approximately 21 nm (210 Angstroms) thick. Seeds were examined using a Cambridge S360 SEM with a backscattered electron detector. Photographs were taken on film and thumbnail positive prints of the images scanned with a Microtek ScanMaker 9800XL. Some images were from earlier work by Prabha Gupta or others using an ISI 40 SEM and scanned prints are shown here. Other SEMs were imaged for us by Sue Lindsay, Microscopy Unit Manager at Macquarie University. Colour photos are from a Leica M125 multi-focus stereo dissector and Leica DFC295 camera.

Voucher specimens are held in the NSW herbarium except where otherwise indicated. The species illustrated, authorities, vouchers and source of the images are listed in Table 1. Full collection details are available at the Atlas of Living Australia (www.ala.org.au). Photographs of seeds of some taxa have previously been published (Briggs and Johnson 1999, 2004, 2012); some of these are repeated to give a more comprehensive coverage here. The sequence in which the images are placed (in Figs 2–13) and the taxa discussed largely follows the order in which the branches arise in the cladogram (Fig. 1), but with multi-focus images (Figs 12 and 13) separate from SEM images.

The mass of some seeds and fruits, dissected from dry voucher specimens, was determined using a Mettler Toledo ME204 balance sensitive to 0.1 mg. Where a number of seeds or fruits were available these were weighed together to give an average weight. Standard deviations for the measurements were not determined because few seeds were available for most species and therefore only general comparisons were sought.

Most of the scanning electron microscopy was done by one of us (CC), with the other (BB) responsible for collecting many of the specimens, multi-focus photography and assembling the manuscript. We did not investigate the chemical composition of the surface structures nor generally the underlying cellular structure where it was obscured by surface features.

Table 1. Taxa studied for seeds or fruit, voucher specimens, relevant figures, and source of images.

Taxon	Voucher	NSW accession[1]	Figs	Image[2]
Alexgeorgea nitens (Nees) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 6759	406919	12a, b	BB
Anarthria barbata R.Br.	B.G. Briggs 9602b	716658	–	–
Anarthria dioica (Steud.) C.I.Fomichev	B.G. Briggs 7654	406590	2c, d	CC
Anarthria humilis Nees	P.G. Wilson 5414	101312	2e, f	CC
Anarthria polyphylla Nees	B.G. Briggs 8510	212695	2g, h	CC
Anarthria prolifera R.Br.	R. Melville 4435	406671	2i, j	CC
Anarthria scabra R.Br.	K. Hill 4554	279690	2a	CC
Anarthria scabra	R. Melville 4416	406560	2b	CC
Aphelia cyperoides R.Br	S.W.L. Jacobs 6932	293103	3e, f	SL
Apodasmia brownii (Hook.f.) B.G.Briggs & L.A.S.Johnson	A.C. Beauglehole 1999	96033	6m, n, o	SL
Apodasmia ceramophila B.G.Briggs & L.A.S.Johnson	K. Meney 912	382910	7a	SL
Baloskion gracile (R.Br.) B.G.Briggs & L.A.S.Johnson	O.D. Evans s.n.	54119	10g, h	PG

Taxon	Voucher	NSW accession[1]	Figs	Image[2]
Baloskion pallens (R.Br.) B.G.Briggs & L.A.S.Johnson	L.A.S. Johnson 8656	367690	10e, f	CC
Baloskion stenocoleum (L.A.S.Johnson & O.D.Evans) B.G.Briggs & L.A.S.Johnson	O.D. Evans s.n.	61054	10i	CC
Baloskion tenuiculme (S.T.Blake) B.G.Briggs & L.A.S.Johnson	L.A.S. Johnson s.n.	55370	10j, k	PG
Baloskion tetraphyllum (Labill.) B.G.Briggs & L.A.S.Johnson ssp. *meiostachyum* L.A.S.Johnson & O.D.Evans	E.F. Constable s.n.	48995	10 l	PG
Baloskion tetraphyllum (Labill.) B.G.Briggs & L.A.S.Johnson ssp. *tetraphyllum*	D.A & D.V. Ratkowsky 1213	368012	10m, n	PG
Baloskion tetraphyllum (Labill.) B.G.Briggs & L.A.S.Johnson ssp. *tetraphyllum*	D.A & D.V. Ratkowsky 1213	368012	10o	SL
Calorophus elongatus Labill.	B.G. Briggs 7062	252353	12c	BB
Calorophus erostris (C.B.Clarke) L.A.S.Johnson& B.G.Briggs	B.G. Briggs 9107	264692	6d	SL
Calorophus erostris	B.G. Briggs 7020	1003819	12d	BB
Catacolea enodis B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7729	391577	11a, b, c	CC
Centrolepis fascicularis Labill.	P.H. Raven 25926	655460	3c, d	SL
Chaetanthus aristatus (R.Br.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 812	94746	12f	BB
Chaetanthus tenellus (Nees) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 589	95201	12g	BB
Chordifex abortivus (Nees) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8702	233041	9f, g	CC
Chordifex amblycoleus (F.Muell.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7575	413911	8m, n	PG
Chordifex capillaceus B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7662	395790	9e	PG
Chordifex chaunocoleus (F.Muell) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8636	232591	9j, k	CC
Chordifex dimorphus (R.Br.) B.G.Briggs & L.A.S.Johnson	E.F. Constable s.n.	48845	9a, b	CC
Chordifex fastigiatus (R.Br.) B.G.Briggs & L.A.S.Johnson	R.H. Cambage 413	47822	9c, d	CC
Chordifex isomorphus (K.W.Dixon & Meney) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7648a	413549	8k, l	PG
Chordifex jacksonii B.G.Briggs & L.A.S.Johnson	S. Pignatti s.n.	876732	8g, h	CC
Chordifex laxus (R.Br.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 664a	96216	8o	PG
Chordifex microcodon B.G.Briggs & L.A.S.Johnson	B.G. Briggs 852	95101	8i, j	CC
Chordifex sinuosus B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7445	446290	9h, i	JE
Coleocarya gracilis S.T.Blake	S.T. Blake 13177	48420	11d	CC
Coleocarya gracilis	D.F. Blaxell 139	380560	11e	CC
Cytogonidium leptocarpoides (Benth.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 525	94300	9n, o	CC
Dapsilanthus elatior (R.Br.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7299	362444	7b	CC
Desmocladus castaneus B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8475b	212594	11j, k	CC
Desmocladus confertospicatus (Steud.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8704	233048	11i	CC
Desmocladus elongatus B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7483	256891	11 l	PG
Desmocladus elongatus	B.G. Briggs 7489	252388	13e	BB
Desmocladus eyreanus B.G.Briggs & L.A.S.Johnson	S.W.L. Jacobs 7046	281816	11f	CC
Desmocladus laxiflorus (Steud.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 6606	391585	11g, h	CC
Desmocladus myriocladus (Gilg) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7781	256967	11m	CC
Desmocladus parthenicus B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8607	233339	11n, o	SL
Desmocladus quiricanus B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7920	209348	13f	BB
Dielsia stenostachya (W.Fitzg.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 9030	1099056	9 l, m	CC
Empodisma gracillimum (F.Muell). L.A.S.Johnson & D.F.Cutler	B.G. Briggs 10079	870968	12e	BB
Eurychorda complanata (R.Br.) B.G.Briggs & L.A.S.Johnson	A.B. Rose 18	391889	6e, f	CC
Gaimardia setcea Hook.f.	B.G. Briggs 9515	494431	3a, b	SL
Hopkinsia anoectocolea (F.Muell.) D.F.Cutler	B.G. Briggs 6407A	406888	2o	JP
Hopkinsia anoectocolea	B.G. Briggs 7624	299309	2n	CC
Hypolaena caespitosa B.G.Briggs & L.A.S.Johnson	B.G. Briggs 6731	265266	6i	CC
Hypolaena exsulca R.Br.	B.G. Briggs 8581	233287	6 l	CC
Hypolaena grandiuscula F.Muell.	B.G. Briggs 8444b	213095	6g	CC
Hypolaena humilis (Gilg) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7832	265375	6h	CC
Hypolaena pubescens (R.Br.) Nees	K. Meney s.n.	254915	6j	CC

Taxon	Voucher	NSW accession[1]	Figs	Image[2]
Hypolaena viridis B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8359a	264041	6k	CC
Lepidobolus preissianus Nees	B.G. Briggs 6762B	299723	13a	BB
Lepidobolus preissianus	B.G. Briggs 7494	299467	13b	BB
Leptocarpus decipiens B.G.Briggs	B.G. Briggs 6737	299926	12k	BB
Leptocarpus denmarkicus (Suesseng.) B.G.Briggs	B.G. Briggs 880a	94918	12n, o	BB
Leptocarpus laxus (R.Br.) B.G.Briggs	B.G. Briggs 8675	232887	7g, h	CC
Leptocarpus scariosus (R.Br.) B.G.Briggs	B.G. Briggs 9977	784604	12 l, m	BB
Leptocarpus tenax (Labill.) R.Br	B.G. Briggs 10187	1004152	12h, i	BB
Leptocarpus thysananthus B.G.Briggs	B.G. Briggs 8698	232976	7c, d	CC
Leptocarpus thysananthus	M. Koch 2662	48036	12j	BB
Leptocarpus trisepalus (Nees) B.G.Briggs	B.G. Briggs 9060	261649	7e, f	CC
Lepyrodia anarthria F.Muell.	S. Krauss 98	210730	5g, h	CC
Lepyrodia cryptica B.G.Briggs & L.A.S.Johnson	E.F. Constable s.n.	60933	5k	CC
Lepyrodia curvescens B.G.Briggs & L.A.S.Johnson	B.G. Briggs 9018	261933	4 l, m	CC
Lepyrodia drummondiana Steud.	B.G. Briggs 7651	262351	4n, o	CC
Lepyrodia extensa B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7616	262328	6a, b	CC
Lepyrodia flexuosa (Benth.) L.A.S.Johnson & O.D.Evans	A.C. Beauglehole 22238	96075	4c	CC
Lepyrodia fortunata B.G.Briggs & L.A.S.Johnson	B. Conn 3438	226467	5a, b	CC
Lepyrodia glauca (Nees) F.Muell.	B.G. Briggs 6689	262469	4a, b	CC
Lepyrodia heleocharoides Gilg	B.G. Briggs 8355	212349	4d, e	CC
Lepyrodia hermaphrodita R.Br.	B.G. Briggs 7612	262392	6c	CC
Lepyrodia imitans B.G.Briggs & L.A.S.Johnson	S.T. Blake 1314	58317	5 l, m	CC
Lepyrodia leptocaulis L.A.S.Johnson & O.D.Evans	S.T. Blake 23673	567590	5i, j	CC
Lepyrodia monoica F.Muell.	S. Krauss 187	216922	5e, f	CC
Lepyrodia muelleri Benth.	L.A.S. Johnson s.n.	76095	4h, i	CC
Lepyrodia muirii F.Muell.	B.G. Briggs 591a	84835	4f, g	CC
Lepyrodia porterae B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8364	212362	5c, d	CC
Lepyrodia riparia B.G.Briggs & L.A.S.Johnson	B.G. Briggs 6783	260244	5e, f	PG
Lepyrodia scariosa R.Br.	B.G. Briggs 9270	280269	5n, o	CC
Lepyrodia valliculae J.M.Black	J.B. Cleland	AD968071188	4j, k	CC
Loxocarya cinerea R.Br.	B.G. Briggs 8459	212550	7m, n	CC
Loxocarya gigas B.G.Briggs & L.A.S.Johnson	B.G. Briggs 7742	259507	7o	PG
Loxocarya magna Meney & K.W.Dixon	B.G. Briggs 8668	232863	7k	CC
Loxocarya magna	B.G. Briggs 6503	259467	7 l	JP
Loxocarya striata (F.Muell) B.G.Briggs & L.A.S.Johnson subsp. *implexa* Keighery	B.G. Briggs 6666	399270	7i, j	CC
Lyginia barbata R.Br.	B.G. Briggs 9602b	716658	–	–
Lyginia excelsa B.G.Briggs & L.A.S.Johnson	B.G. Briggs 9320	391337	–	–
Lyginia imberbis R.Br.	B.G. Briggs 6671	298859	2m	CC
Lyginia imberbis	B.G. Briggs 7624	299309	2k, l	PG
Melanostachya ustulatus (F.Muell. ex Ewart & Sharman) B.G.Briggs & L.A.S.Johnson	S.W. Jackson	78862	10c, d	CC
Platychorda applanata (Spreng.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 567	94739	8e, f	PG
Sporadanthus caudatus (L.A.S.Johnson & O.D.Evans) B.G.Briggs & L.A.S.Johnson	D.J. McGillivray 2363	94592	3m	CC
Sporadanthus gracilis (R.Br.) B.G.Briggs & L.A.S.Johnson	E. McBarron 8704	65816	3i	JE
Sporadanthus rivularis B.G.Briggs & L.A.S.Johnson	B.G. Briggs 665	95036	3g, h	JE
Sporadanthus strictus (R.Br.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 6548	364397	3j, k, l	CC
Sporadanthus tasmanicus (Hook.f.) B.G.Briggs & L.A.S.Johnson	J.H. Willis s.n.	MEL501865	3n, o	PG
Tremulina cracens B.G.Briggs & L.A.S.Johnson	B.G. Briggs 6931b	413553	8a, b	CC
Tremulina tremula (R.Br.) B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8321	212284	8c, d	CC
Tyrbastes glaucescens B.G.Briggs & L.A.S.Johnson	B.G. Briggs 8349	212330	10a, b	CC

[1] Vouchers are placed in the NSW Herbarium unless another herbarium acronym is given.

[2] Images are by one of us (CC) or (BB), or by PG = Prabha Gupta, SL = Sue Lindsay, JE = Joy Everett or JP = Jocelyn Powell.

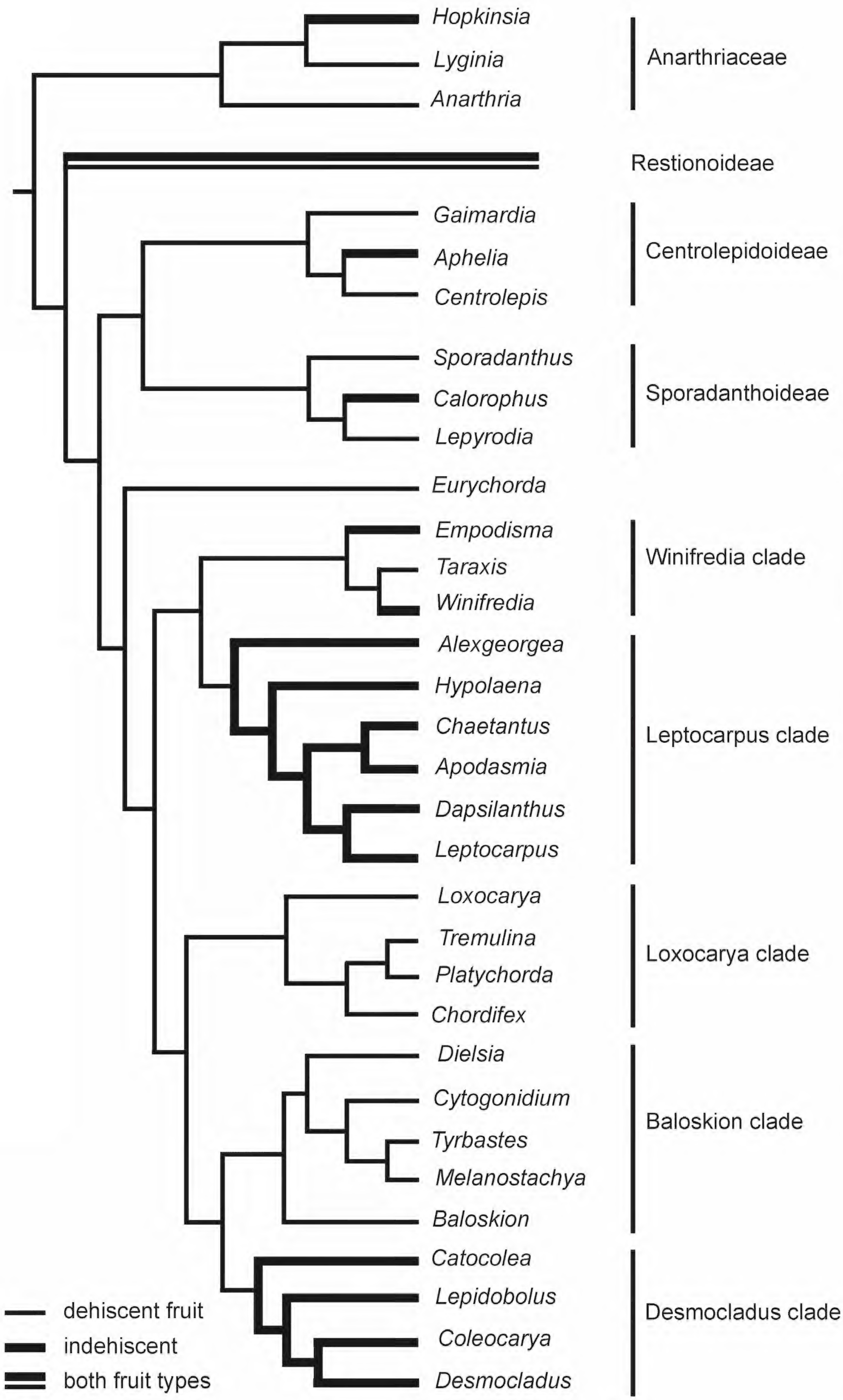

Fig. 1. Cladogram of Anarthriaceae and Restionaceae (the restiid clade of Poales) based on Bayesian analysis of chloroplast data (following Briggs *et. al.* 2014).

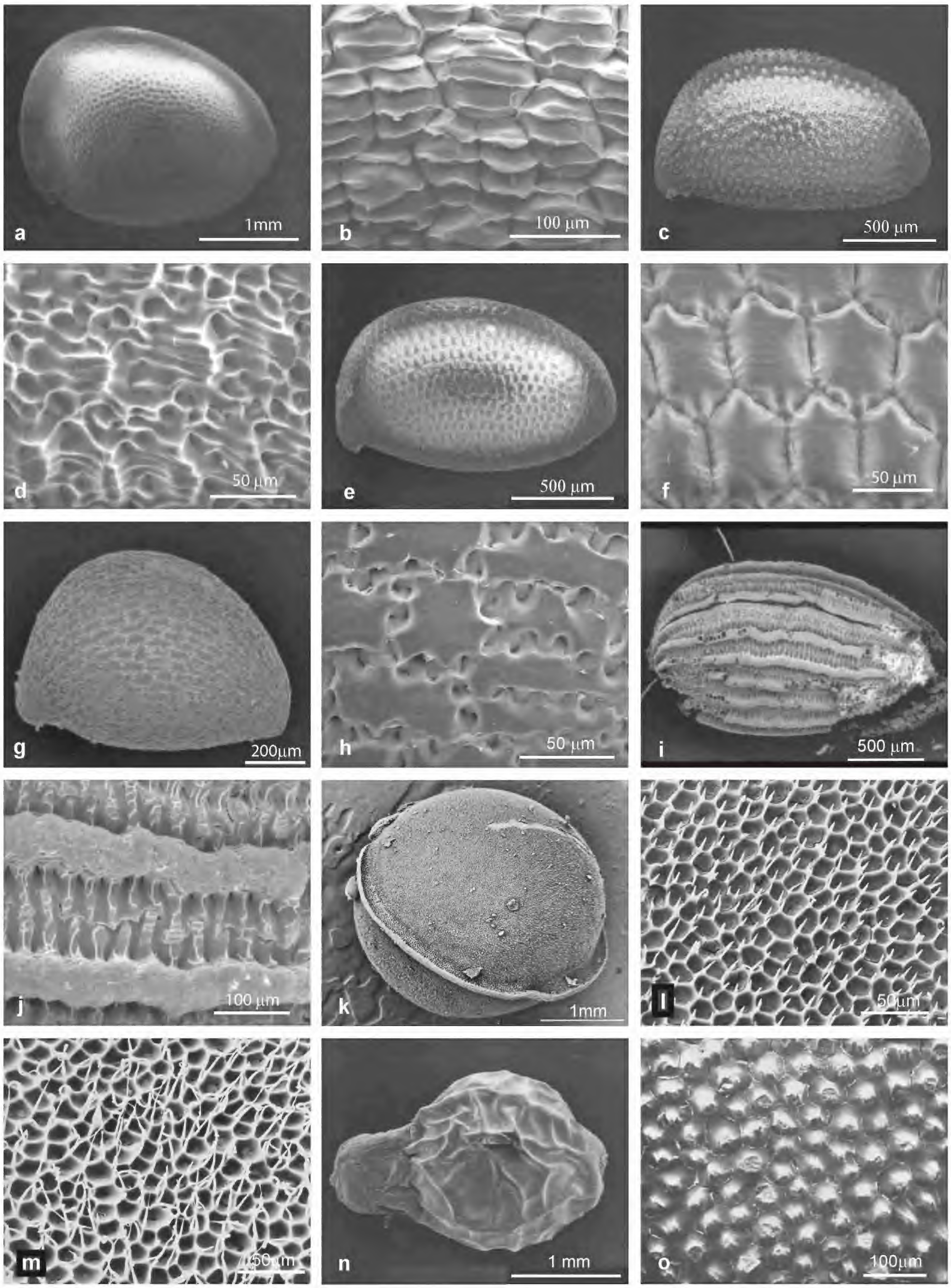

Fig. 2. Seed morphology of Anarthriaceae. Figs 2–13 show SEM images of seeds and seed surface detail unless otherwise noted. The sequence largely follows the order in which the branches arise in Fig. 1, but with multi-focus images (Figs 12, 13) separate from SEM images. Voucher specimens are listed in Table 1 and further details may be found in the *Atlas of Living Australia* (www.ala.org.au). a, b: *Anarthria scabra*. c, d: *A. dioica*. e, f: *A. humilis*. g, h: *A. polyphylla*. i, j: *A. prolifera*. k, l, m: *Lyginia imberbis*. n, o: *Hopkinsia anoectocolea*, fruit, seed surface.

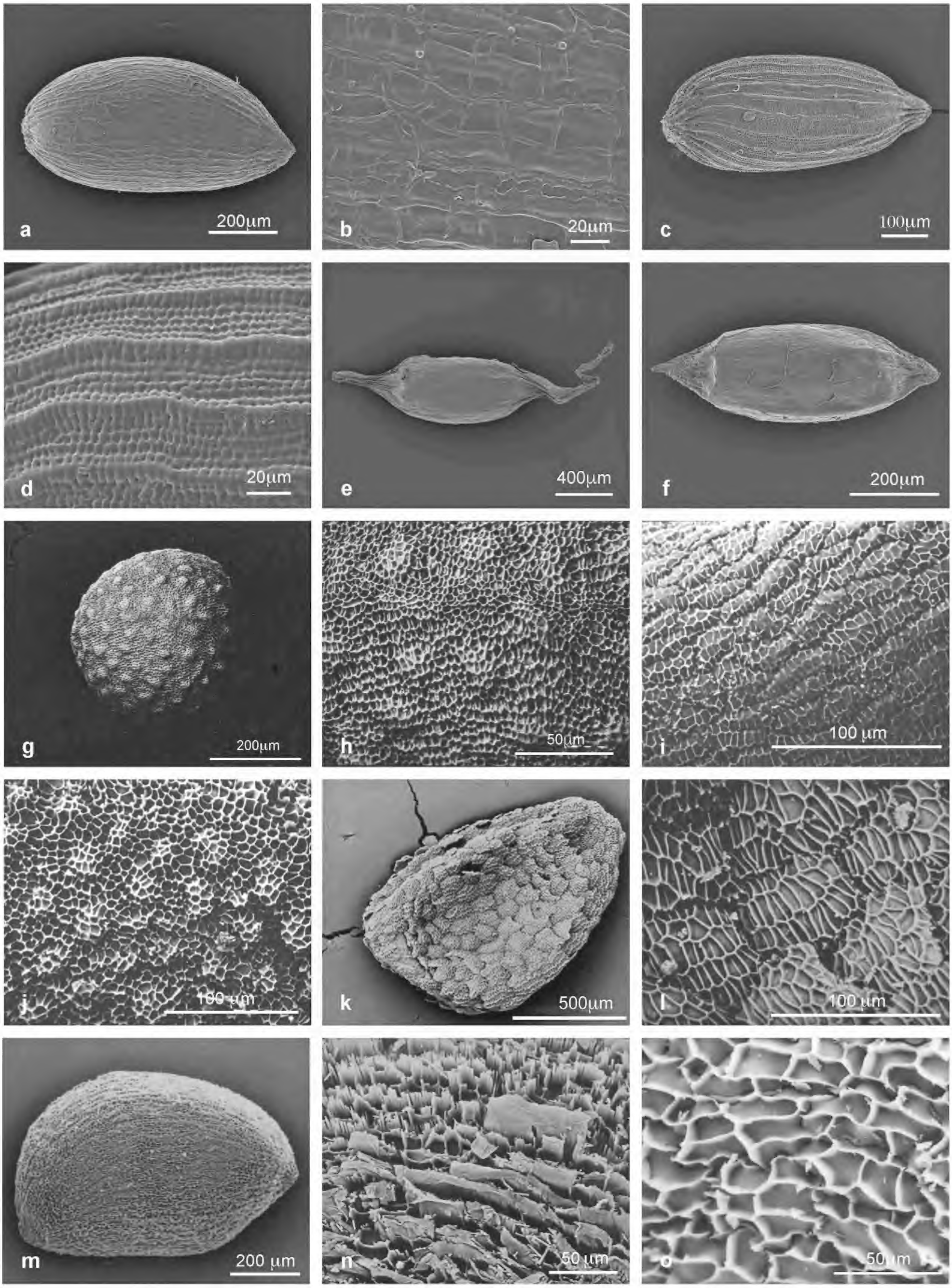

Fig. 3. Seed morphology of Restionaceae, subfamilies Centrolepidoideae and Sporadanthoideae. a, b: *Gaimardia setacea*. c, d: *Centrolepis fascicularis*. e, f: *Aphelia cyperoides* fruit (formed from one of several carpels) and seed. g, h: *Sporadanthus rivularis*. i: *S. gracilis*. j: *S. caudatus*. k, l: *S. tasmanicus*. m, n: *Lepyrodia glauca*. o: *L. flexuosa*.

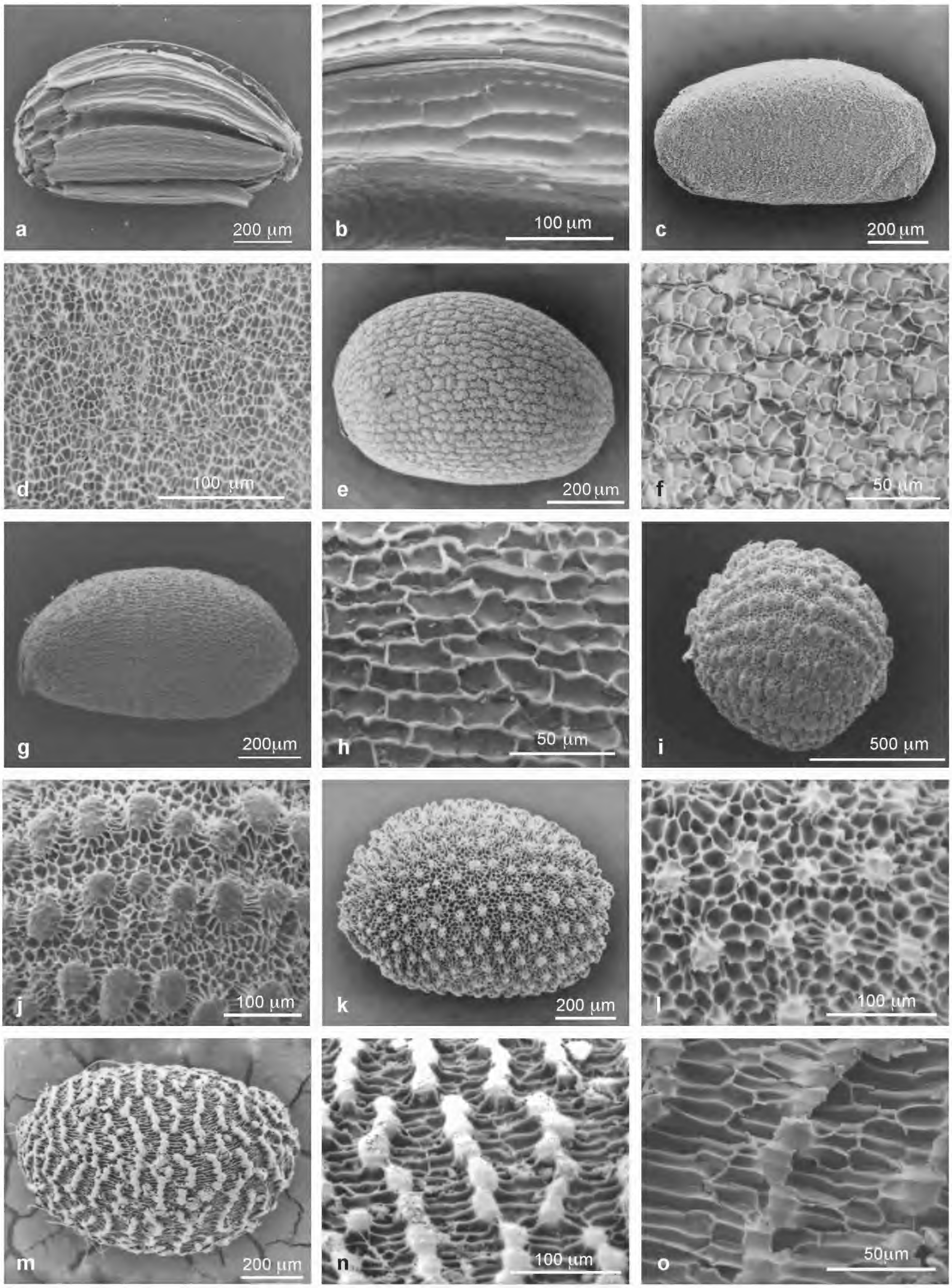

Fig. 4. Seed morphology of Restionaceae, subfamily Sporadanthoideae: *Lepyrodia*. a, b: *L. heleocharoides*. c, d: *L. muirii*. e, f: *L. muelleri*. g, h: *L. valliculae*. i, j: *L. curvescens*. k, l: *L. drummondiana*. m, n, o: *L. monoica*.

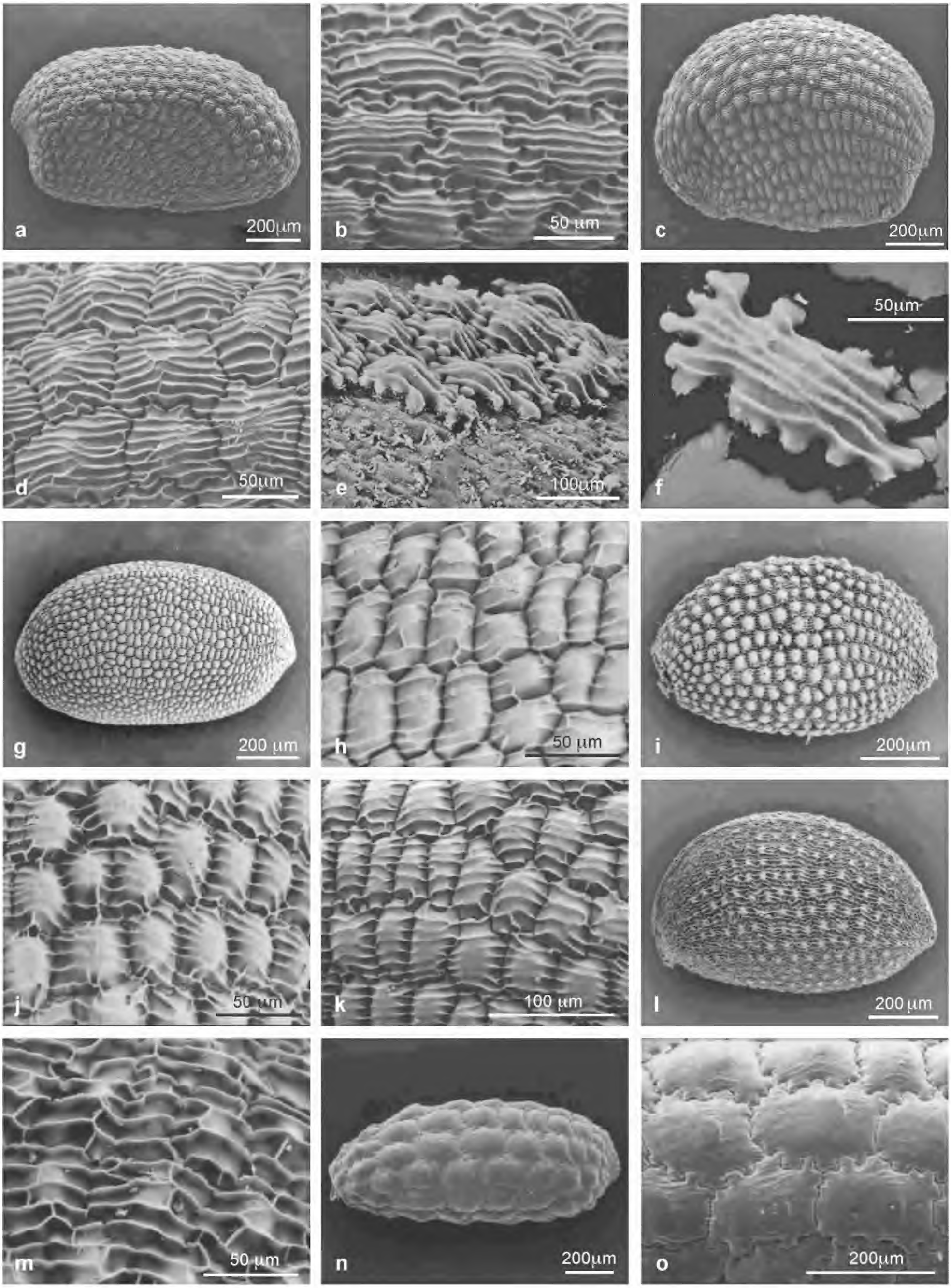

Fig. 5. Seed morphology of *Lepyrodia*: a, b: *L. fortunata*. c, d: *L. porterae*. e, f: *L. riparia,* surface layer partially removed, single surface cell. g, h: *L. anarthria*. i, j: *L. leptocaulis*. k: *L. cryptica*. l, m: *L. imitans*. n, o: *L. scariosa*.

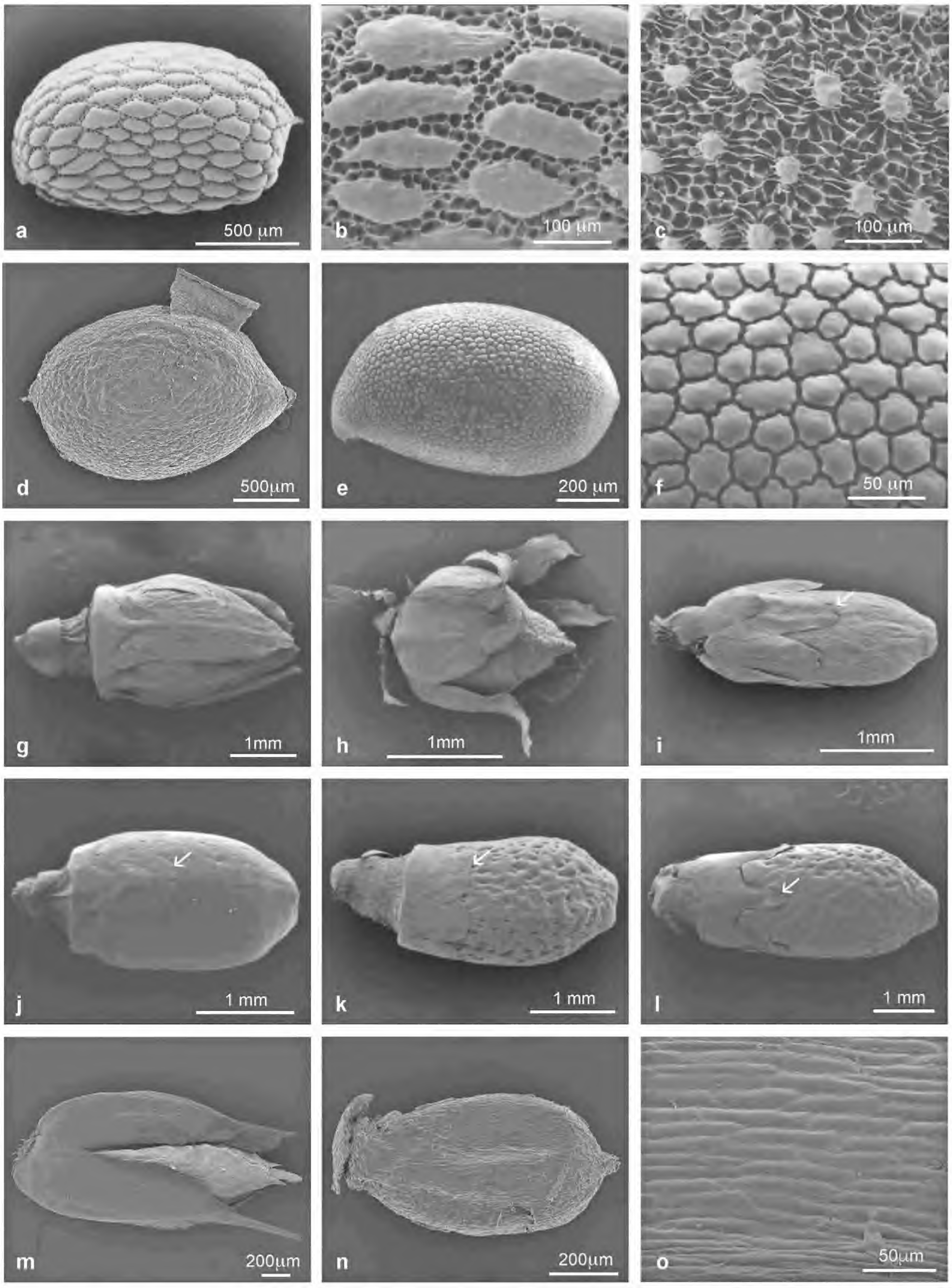

Fig. 6. Seeds and fruit of *Lepyrodia*, *Calorophus*, *Eurychorda, Hypolaena* (fruit with attached tepals and stipe, arrows mark the edge of the appressed tepals) and *Apodasmia*: a, b: *Lepyrodia extensa*. c: *L. hermaphrodita*. d: *Calorophus erostris*, (damaged at upper right). e, f: *Eurychorda complanata*. g: *Hypolaena grandiuscula* enclosed by tepals. h: *H. humilis*. i: *H. caespitosa*. j: *H. pubescens*. k: *H. viridis*. l: *H. exsulca*. m, n, o: *Apodasmia brownii* fruit with tepals and bracts, seed, seed detail.

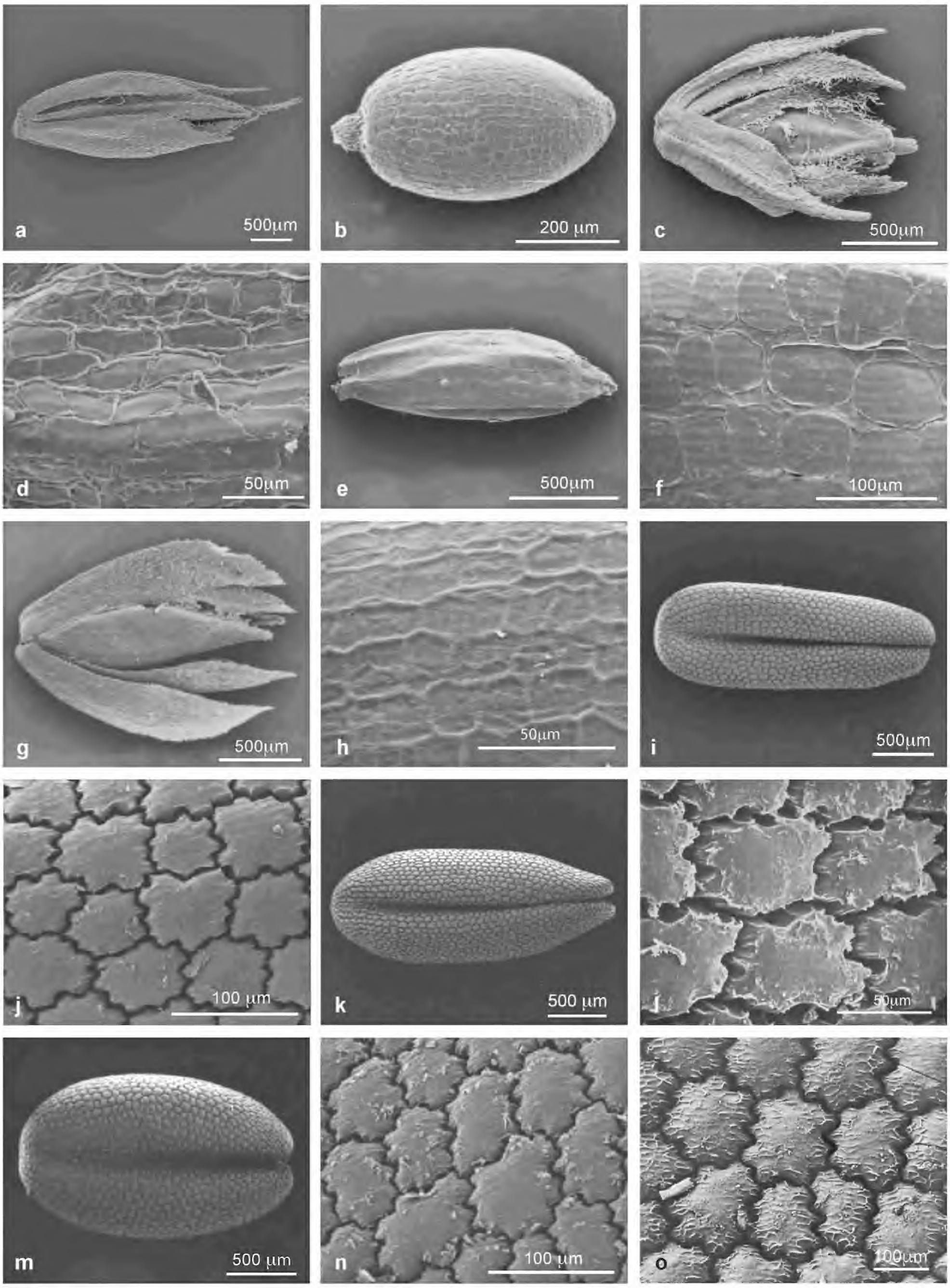

Fig. 7. Seed and fruit of *Leptocarpus* and *Loxocarya* clades: a: *Apodasmia ceramophila* fruit with bracts and tepals. b: *Dapsilanthus elatior*. c, d: *Leptocarpus thysananthus*, fruit with bracts and tepals, seed detail. e, f: *Leptocarpus trisepalus*, seed, seed detail. g, h: *Leptocarpus laxus*, fruit with tepals, seed. i, j: *Loxocarya striata* ssp. *implexa*. k, l: *Loxocarya magna*. m, n: *Loxocarya cinerea*. o: *Loxocarya gigas*.

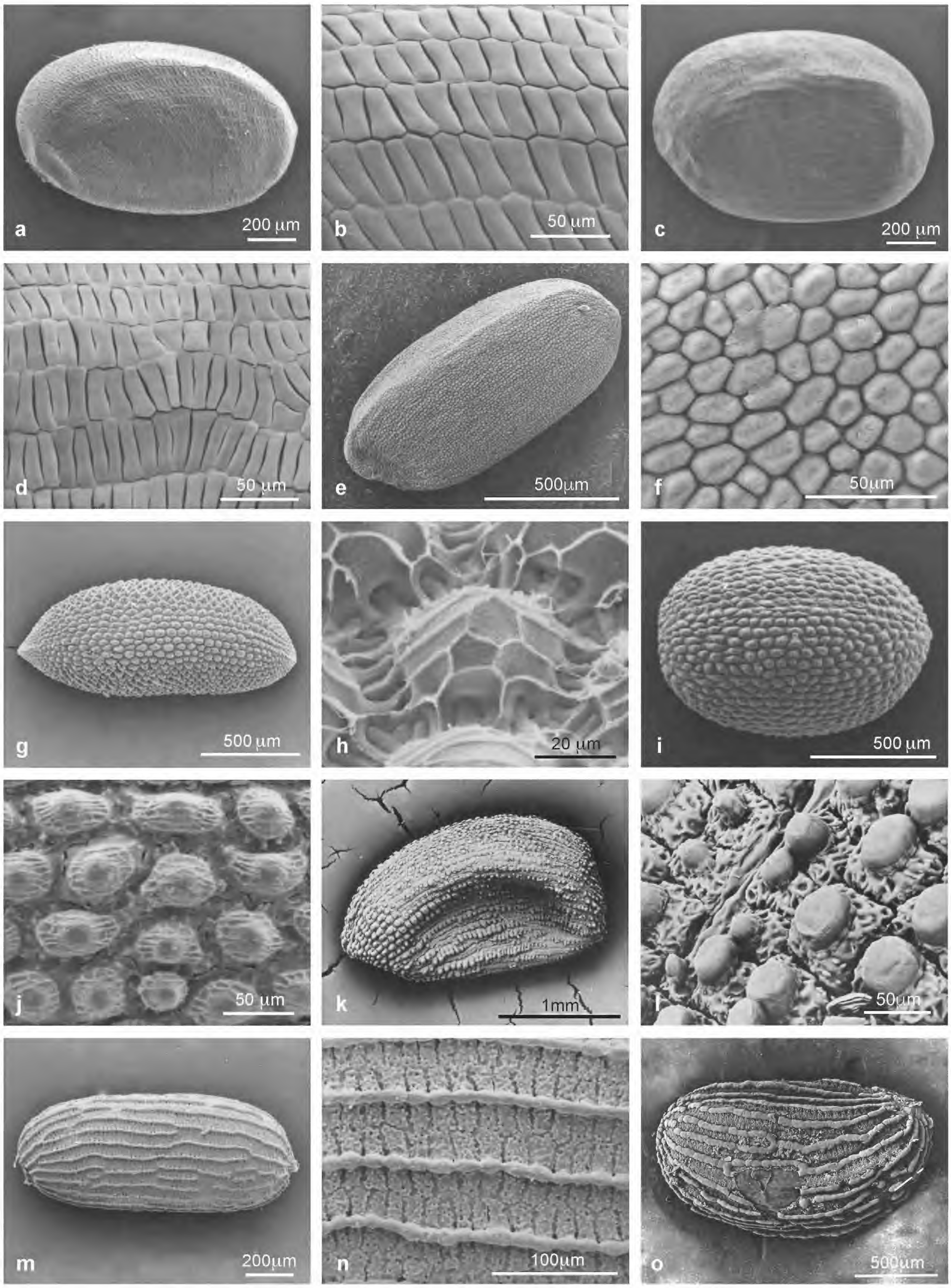

Fig. 8. Seeds of the *Loxocarya* clade: a, b: *Tremulina cracens*. c, d: *T. tremula*. e, f: *Platychorda applanata*. g, h: *Chordifex jacksonii*. i, j: *C. microcodon*. k, l: *C. isomorphus*. m, n: *C. amblycoleus*. o: *C. laxus*.

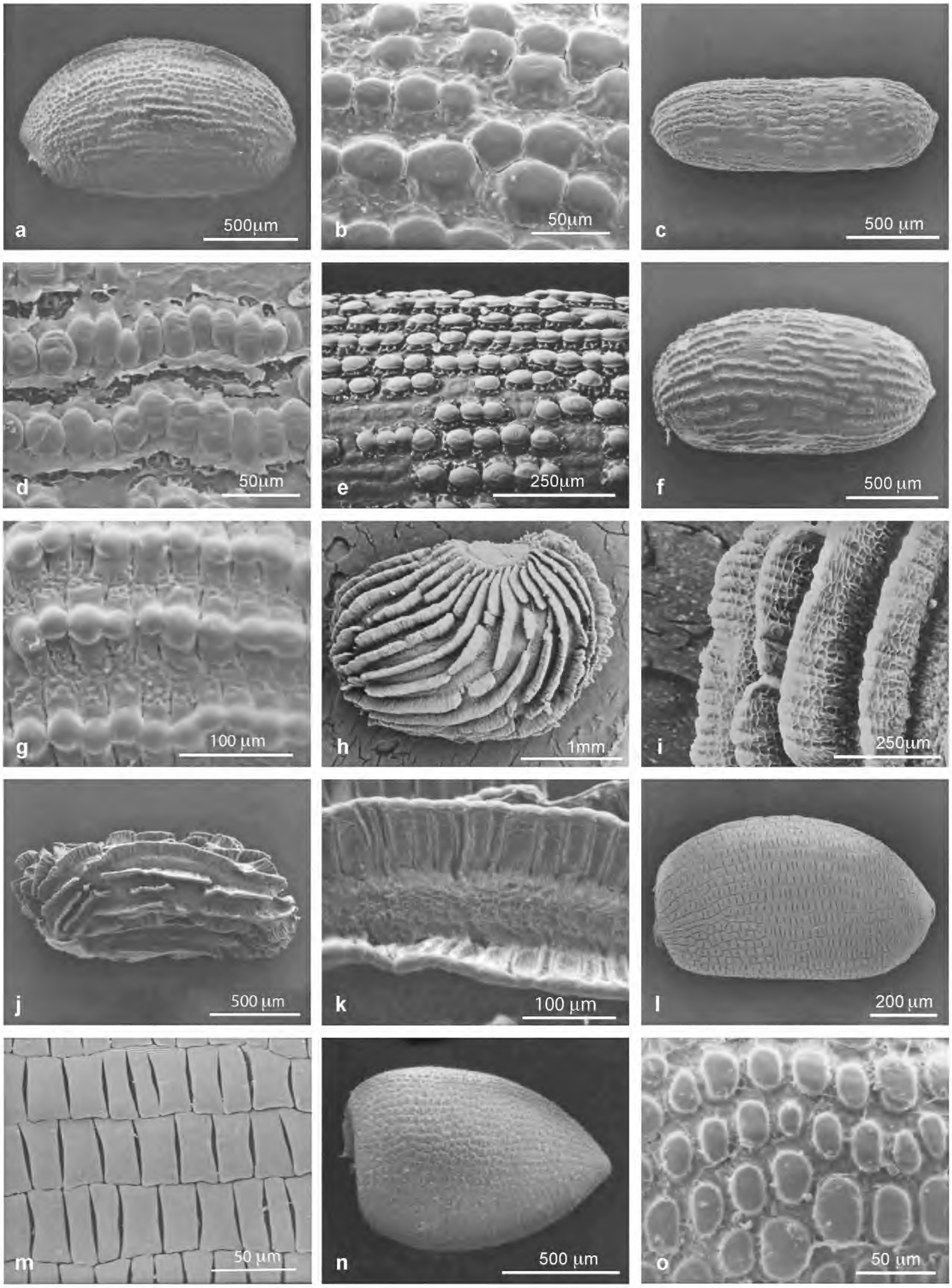

Fig. 9. Seeds of the *Loxocarya* and *Baloskion* clades. a, b: *Chordifex dimorphus*. c, d: *C. fastigiatus*. e: *C. capillaceus*. f, g: *C. abortivus*. h, i: *C. sinuosus*. j, k: *C. chaunocoleus*. l, m: *Dielsia stenostachya*. n, o: *Cytogonidium leptocarpoides*.

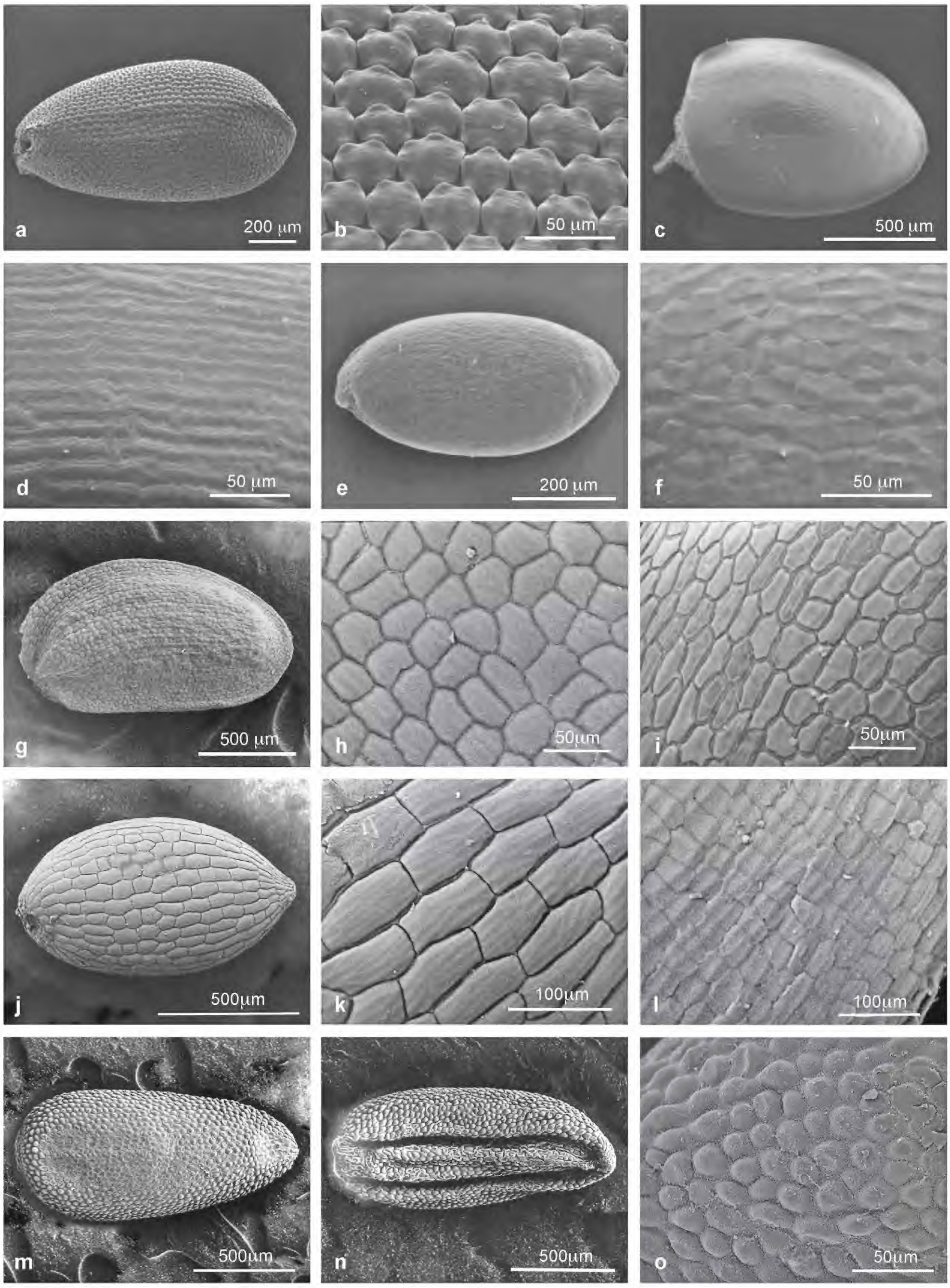

Fig. 10. Seeds of the *Baloskion* clade. a, b: *Tyrbastes glaucescens*. c, d: *Melanostachya ustulata*. e, f: *Baloskion pallens*. g, h: *B. gracile*. i: *B. stenocoleum*. j, k: *B. tenuiculme*. l: *B. tetraphyllum* ssp. *meiostachyum*. m, n, o: *B. tetraphyllum* ssp. *tetraphyllum*.

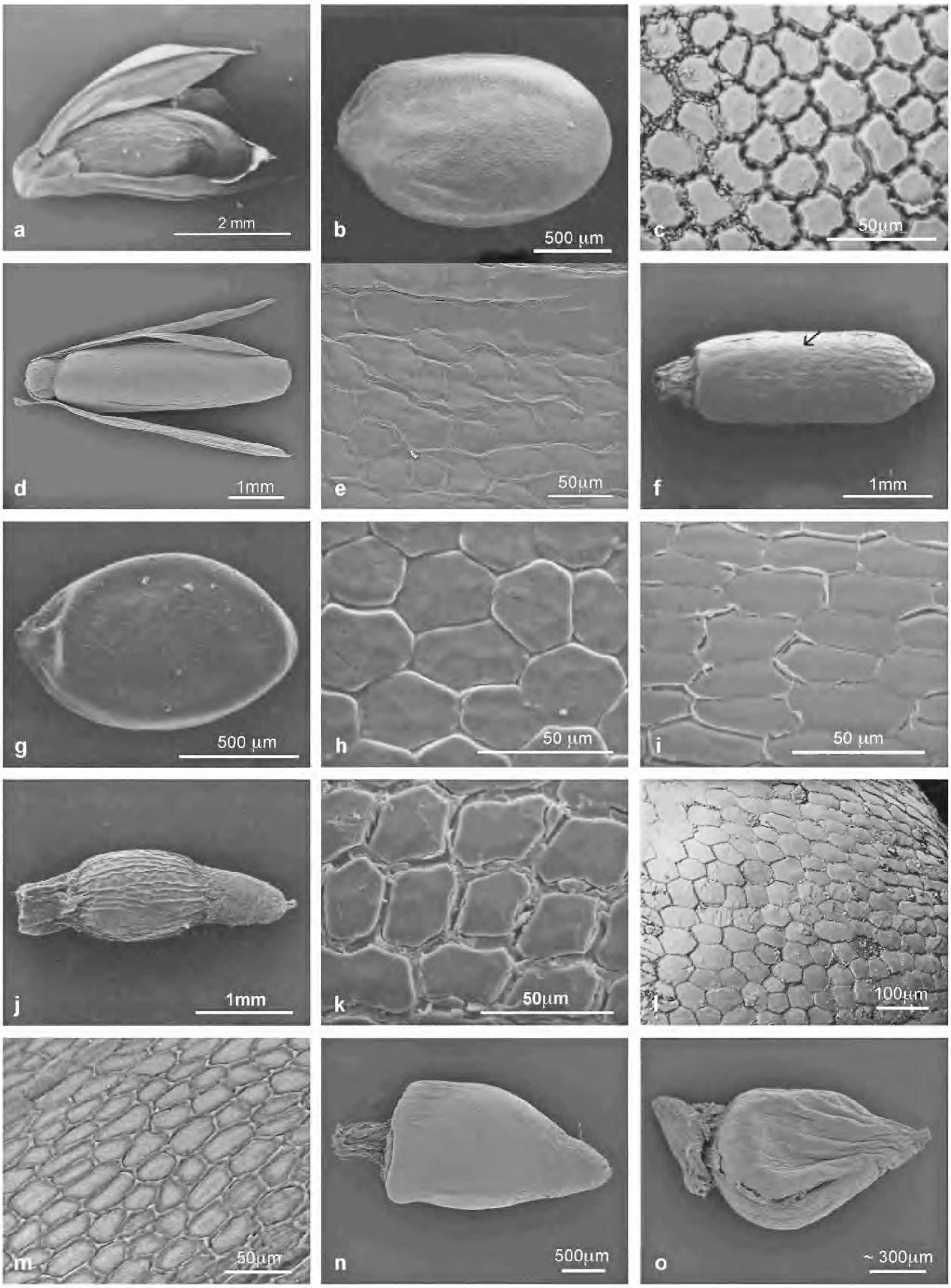

Fig. 11. Fruit and seeds of the *Desmocladus* clade. a, b, c: *Catacolea enodis*, fruit with bracts seed, seed detail. d, e: *Coleocarya gracilis,* fruit with tepals, seed detail. f: *Desmocladus eyreanus*, fruit with tepals, arrow marks the edge of an appressed tepal. g, h: *D. laxiflorus*. i: *D. confertospicatus*. j, k: *D. castaneus,* fruit, seed detail. l: *D. elongatus*, seed detail. m: *D. myriocladus*. n, o: *D. parthenicus*, fruit tightly encased in surrounding rigid bract, fruit removed from bract.

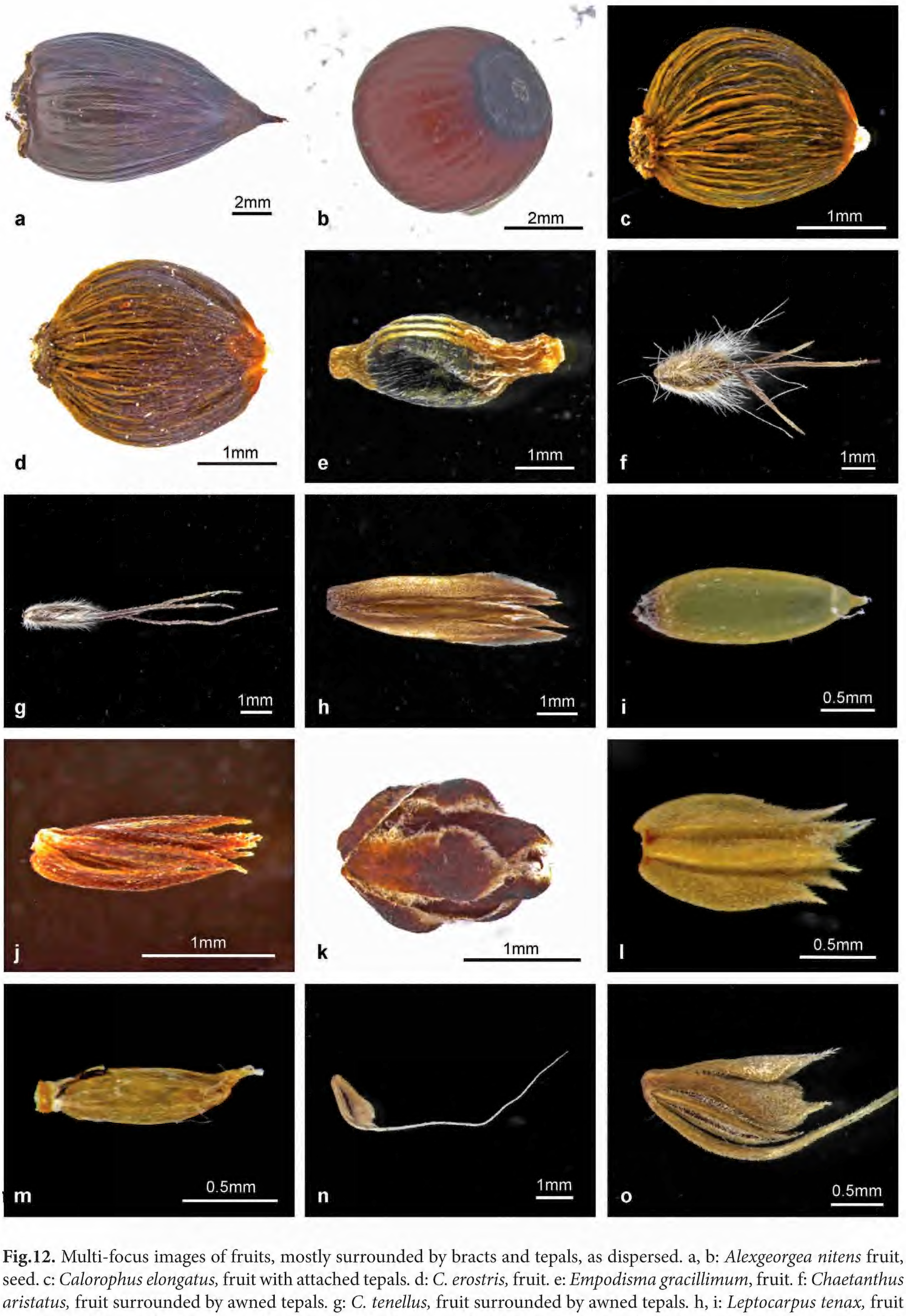

Fig.12. Multi-focus images of fruits, mostly surrounded by bracts and tepals, as dispersed. a, b: *Alexgeorgea nitens* fruit, seed. c: *Calorophus elongatus,* fruit with attached tepals. d: *C. erostris,* fruit. e: *Empodisma gracillimum*, fruit. f: *Chaetanthus aristatus,* fruit surrounded by awned tepals. g: *C. tenellus,* fruit surrounded by awned tepals. h, i: *Leptocarpus tenax,* fruit surrounded by tepals, fruit. j: *L. thysananthus,* fruit surrounded by bract and tepals. k: *L. decipiens,* fruit surrounded by bracts and tepals. l, m: *L. scariosus,* fruit surrounded by bracts and tepals, fruit. n, o: *Leptocarpus denmarkicus,* fruit surrounded by bracts and tepals, one bract expanded into a long awn, two outer tepals spathulate.

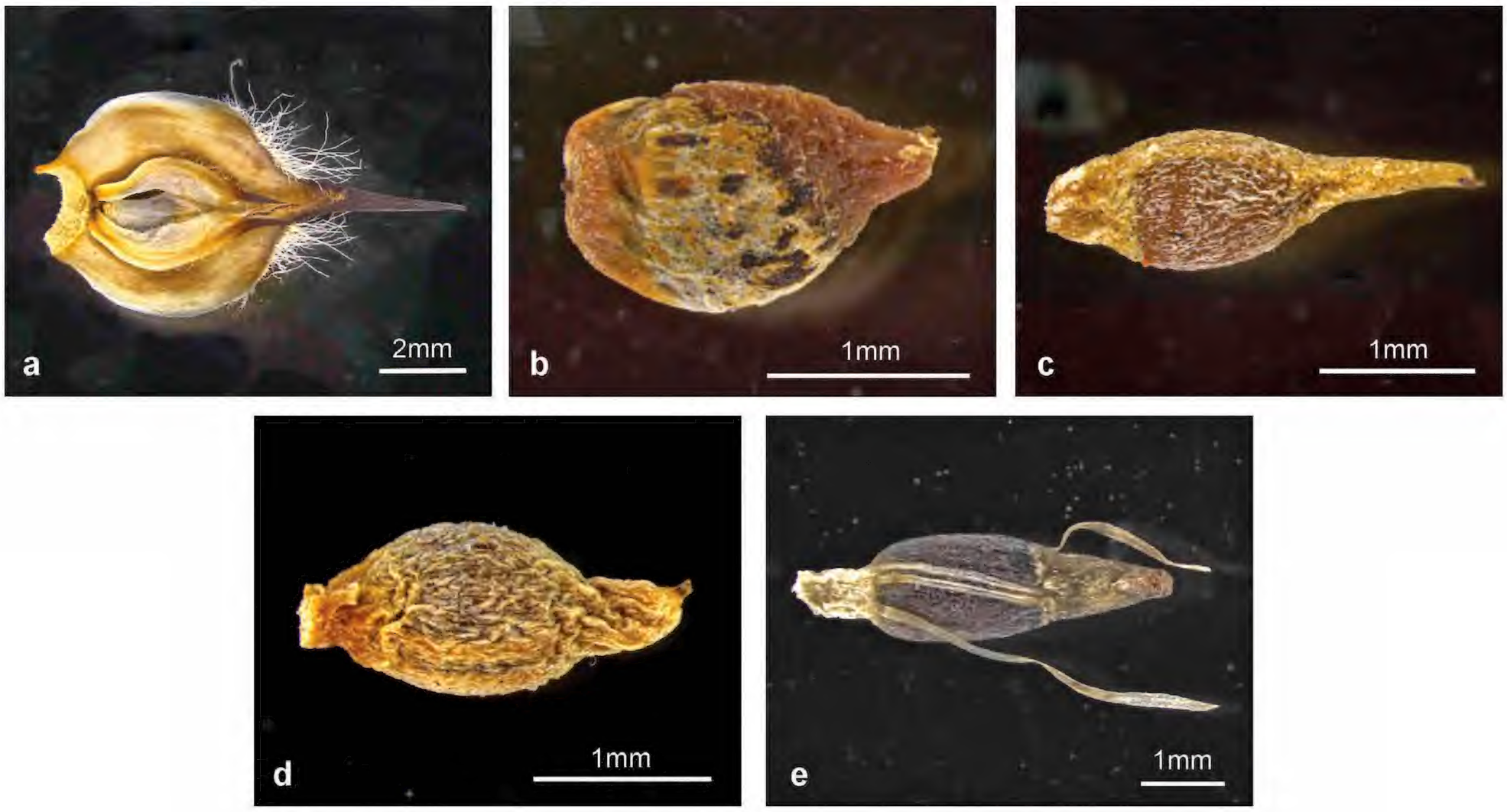

Fig. 13. Multi-focus images of fruits, mostly surrounded by bracts and tepals, as dispersed. a, b: *Lepidobolus preissianus,* fruit attached to glume with tepals, fruit. c: *Desmocladus myriocladus*, fruit. d: *D. quiricanus*, fruit. e: *D. elongatus*, fruit with tepals, showing lateral lines and stout stylar beak.

Results

Diaspore type and ornamentation

Anarthriaceae

The three genera, *Anarthria* (Figs 2a–j), *Lyginia* (Figs 2k–m) and *Hopkinsia* (Figs 2n–o) have very different seeds and fruit. Until recently, six species were recognised in *Anarthria* (e.g. Briggs *et al.* 2020a), but *A. gracilis*, as formerly recognised, has been shown to be a complex of three species (Fomichev *et al.* 2021). *Anarthria dioica* (Figs 2c, d) is newly recognised by Fomichev *et al.* (2021). Seeds of *Anarthria* have a brittle white outer layer of cells and a pattern of relatively large cells in longitudinal rows. The rows are indistinct in *A. dioica* and *A. scabra*, distinct in *A. humilis* but very prominent in *A. prolifera*. Cells are polygonal in *A. humilis* with some minor lobing but intricately lobed in *A. polyphylla*. In *A. prolifera* the cells meet in the 'valley' between the ridges and each cell has a convex central portion forming part of a ridge and narrow elongated 'wings' with heavily thickened radial walls forming the slopes of a 'valley' between the ridges. Longitudinal sculpturing overlays the cells, distinct in *A. scabra*, faint in *A. humilis* but complex and irregular in *A. dioica*.

The three species of *Lyginia* all have similar seeds of a very distinctive type: almost spherical, with a brittle white outer layer, and with a hyaline flange encircling the seed in the median vertical plane and the surface marked by small concavities—each the surface of a cell—with short fragile spicules arising at the angles of the cells (Figs 2k–m). Sections of seeds show a palisade-like outer layer of narrow thick-walled cells, much taller than wide, with the outer surface concave. *L. imberbis* showed considerable variation in the length of the spicules, short in Fig. 2l but longer in Fig. 2m. In examples studied of *L. excelsa* the projections were uniformly short, similar to Fig. 2l, but in *L. barbata* the straight, filiform projections perpendicular to the seed surface were up to four times longer than the width of the surface cells.

Hopkinsia has small nut fruits (Fig. 2n, o), shed with the attached stout pedicel which may act as an elaiosome. A pale lateral line marks the carpel margins and the style bases persist as three small apical peaks. The inner layer of the perianth is woody but the outer layer is fleshy, although fairly thin, and red when young, aging to brown (Meney *et al.* 1999c). If the red colour and fleshy consistency suggests that some dispersal agent is attracted to the fruits while still on the plant, this would be unique in the restiid clade. The seed surface shows convex polygonal cells overlain by longitudinal striations, presenting more relief than is usual in indehiscent fruits.

Restionaceae subfamily Centrolepidoideae

We have included only a token sampling of the centrolepid clade, which deserves further study. Examples of *Gaimardia*, *Aphelia* and *Centrolepis* (Figs 3a–f), have small, ovoid seeds, smooth or marked by longitudinal ridges. *Aphelia* is indehiscent whereas the other genera have loculicidal capsules (Cooke 1998, Sokoloff *et al.* 2015) with the carpels of *Aphelia* and *Centrolepis* separated on an elongated receptacle. In *Aphelia cyperoides* the seed is visible through the membranous pericarp which is readily opened along the suture line. *Aphelia* and *Centrolepis* have the smallest and lightest seeds reported in the Restionaceae, with a mass of 0.08–0.2 mg (Table 2).

Table 2. Seed and fruit dry weight of some species of Anarthriaceae and Restionaceae. Genera are listed mostly in the order in which the branches arise in the cladogram Fig. 1.

Taxon	Voucher NSW accession or reference	Number of items averaged	Seed or fruit weight (mg)	Description
Anarthriaceae				
Anarthria scabra	279690	5	4.6	seed
Hopkinsia anoectocolea	391550	7	3.6	fruit + stipe
Lyginia imberbis	–	10	3.02	seed
Lyginia imberbis	279735	1	1.9	seed
Restionaceae				
Centrolepidoideae				
Gaimardia setacea	494431	3	0.3	seed
Aphelia cyperoides	293103	8	0.2	seed
Centrolepis fascicularis	655460	16	0.08	seed
Sporadanthoideae				
Sporadanthus rivularis	870999	6	0.37	seed
Calorophus elongatus	264835	1	4.2	fruit
Calorophus erostris	264692	6	5.7	fruit
Lepyrodia macra	–	11	0.31	seed
Lepyrodia scariosa	280324	9	0.23	seed
Leptocarpoideae				
Alexgeorgea ganopoda	Meney *et al.* (1990)	–	605	seed
Alexgeorgea nitens	Meney *et al.* (1990)	–	190	seed
Alexgeorgea nitens	1100291	1	265	fruit
Alexgeorgea subterranea	Meney *et al.* (1990)	–	162	seed
Alexgeorgea subterranea	1100294	9	256	fruit
Hypolaena caespitosa	232897	10	2.27	fruit + stipe & tepals
Hypolaena exsulca	233287	6	4.7	fruit + stipe & tepals
Hypolaena exsulca	232625	5	4.5	fruit + stipe & tepals
Hypolaena robusta	233255	1	10.2	fruit + stipe & tepals
Leptocarpus denmarkicus	409883	12	0.025	fruit
Leptocarpus laxus	232887	55	0.224	fruit + tepals
Leptocarpus trisepalus	261649	31	1.07	fruit + tepals & bracts
Loxocarya gigas	233295	20	12.54	seed
Loxocarya magna	232863	15	3.35	seed
Loxocarya striata ssp. *striata*	233343	38	2.71	seed
Loxocarya striata ssp. *implexa*	399270	7	2.27	seed
Chordifex abortivus	233041	6	0.52	seed
Chordifex chaunocoleus	232591	7	0.27	seed
Chordifex stenandrus	233330	75	0.114	seed
Tyrbastes glaucescens	261643	13	0.36	seed
Lepidobolus chaetocephalus	233333	7	0.19	fruit
Lepidobolus preissianus ssp. *preissianus*	299471	5	2.96	fruit
Coleocarya gracilis	052329	14	3.72	fruit + tepals
Desmocladus lateriticus	209307	10	0.8	fruit

Restionaceae subfamily Sporadanthoideae

Seed shape in *Sporadanthus* ranges from spherical to cylindrical with cells arranged in longitudinal rows in the species with cylindrical seeds. All have a network of narrow ridges overlaying the cells (Figs 3g–l), a tertiary sculpture in the terminology of Barthlott (1981). The prominent ridges in *S. strictus* appear to be similar to those of *Anarthria prolifera* in that the cells extend from 'valley' to 'valley' with a convex central portion of the cell forming a segment of a ridge. de Lange *et al.* (1999) described the surfaces of the New Zealand *Sporadanthus traversii* seeds as having bi-reticulate surface with rectangular to rectangular-polygonal primary ridges and prominent secondary ridges, while in *S. ferrugineus* the secondary pattern is obscure to weak and irregular.

Lepyrodia seeds (Figs 3m–o, 4, 5, 6a–c) are highly diverse with *L. glauca, L. flexuosa, L. muelleri* and *L. valliculae* having an intricate network of narrow plates overlying the cells, reminiscent of the surfaces of *Sporadanthus* seeds. This appears to be a plesiomorphic condition for *Lepyrodia*. In most species the epidermal cells are arranged in more or less prominent longitudinal files. In *L. curvescens* (Fig. 4i, j) and *L. hermaphrodita* (Fig. 6c) the seeds are colliculate with the convexities each centred on a cell and with a network of superficial ridges spreading radially from the centre of the cell. In many species (Fig. 5a–m) the cells are overlain by prominent longitudinal ridges, but longitudinal striations are scarcely expressed in *L. scariosa*. A longitudinal pattern not involving convex cells is even more prominent in *L. heleocharoides* (Figs 4a, b) in which the cell structure is obscured. *L. scariosa* (Fig. 5n, o) is notable for its very large-cell pattern. Specimens of *L. scariosa* can be difficult to distinguish from *L. cryptica* (Fig. 5k), *L. imitans* (Fig. 5l, m) and *L. verruculosa* unless the seed surface morphology, or the corresponding pattern imprinted on the inner surface of the capsule, can be seen, so this is an important feature for identifying female plants. The similarity of seeds in *L. curvescens* (Fig. 4i, j) and *L. drummondiana* (Fig. 4k, l) accords with their close relationship in the phylogeny of Briggs *et al.* (2014), but other groupings in the phylogeny such as *L. glauca* sister to *L. heleocharoides* or (*L anarthria* (*L. muelleri* + *L scariosa*)) are not shown in seed features. The DNA phylogeny showed poor resolution within *Lepyrodia*, with few branches supported in both the Bayesian and PAUP analyses, so did not clearly suggest relationships within the genus.

Calorophus (Figs 6d, 12c, d) has three separate styles but only a single loculus and develops small indehiscent nuts with a woody pericarp, almost spherical but less convex adaxially where there is an indistinct furrow, opposite an indistinct ridge abaxially. The fruit surface is longitudinally furrowed and the seed surface consists of slightly convex polygonal cells.

Restionaceae subfamily Leptocarpoideae

Analyses of DNA chloroplast data (Briggs *et al.* 2000, 2010, 2014) show *Eurychorda complanata*, the sole species of its genus, sister to the remainder of Leptocarpoideae. It has 2-locular capsules and smooth seeds with thick-walled cells separated at the surface by deep clefts (Fig. 6e, f).

Unfortunately, we have not studied seeds of the *Winifredia* clade. It comprises the monotypic genera *Winifredia* (*W. sola*) and *Taraxis* (*T. grossa*) with *Empodisma* (three species). Meney *et al.* (1999c) described *Winifredia* as having small indehiscent nut fruits and *Taraxis* as having capsular fruit. In the absence of observations of our own, we accept those descriptions but note that, except for *Taraxis*, the whole branch of the tree (Fig. 1) that includes both the *Winifredia* and *Leptocarpus* clades is characterised by indehiscent fruit. Both *Winifredia* and *Taraxis* retain three style branches (rarely only two in *Taraxis*) but female flowers of *Taraxis* are often galled and fruits are very rarely produced. The ovary of *Taraxis* is 'unilocular, laterally thickened on two edges' (Briggs and Johnson 1998). No fruits of *Winifredia* were seen in the NSW and HO herbaria; the gynoecium has a single loculus and ovule. Both Australian species of *Empodisma*, *E. minus* and *E. gracillimum*, have globular, pale or dark brown, glossy fruit, c. 1.5 mm diam., with a thin pericarp (Fig. 12e) and a pale abaxial longitudinal line, but—although *E. minus* is very widespread and often abundant—we have not seen mature seed. Wagstaff and Clarkson (2012) note that few specimens they examined had mature fruits but described fruits of *E. minus* and *E. gracillimum* as ovoid 1-seeded nuts and illustrated them showing a pronounced lateral ridge.

All of the *Leptocarpus* clade have indehiscent fruit and most are dispersed with perianth and bracts attached. *Alexgeorgea* (Figs 12a, b) and *Hypolaena* (Figs 6g–l), the two basal branches, have nuts with a woody pericarp. In most of *Hypolaena* the tepals are closely appressed and the pedicel stout. *Alexgeorgea* is highly unusual in having female flowers borne on short branches arising from the rhizomes, with the base of the flower and surrounding bracts below ground level, only the tips of erect scarious bracts (cataphylls) and tepals and the 3-branched style emerging. The female spikelets mostly develop a single flower but sometimes two flowers are observed within the same group of enclosing cataphylls (E.M. Sandiford pers comm.). The nuts (9–11 mm diam.) are much larger and more massive than any other Restionaceae and exceed in mass the largest fruits of the African Restionaceae, such as *Cannomois grandis* (Table 2, Caddick and Linder 2002). The rhizomes are long and slender and field observations suggest that plants form patches to 15 m across (Briggs *et al.*

2020b). Rhizome growth alone may distribute seeds well away from the site of germination of the parent plant. *Chaetanthus*, *Apodasmia, Dapsilanthus* and *Leptocarpus* (Figs 7a–h, 12f–o) have a thin membranous or papery pericarp. In some species the attached tepals are inflated (*L. trisepalus*, Fig. 7e, f) or wing-like, or are expanded into awns and covered with long hairs (*Chaetanthus* Fig. 12f, g). Fruits of *L. denmarkicus* (Fig. 12n, o) are shed with two bracts elongated into awns, one of them much longer than the other. In all these indehiscent fruits, the seed surfaces are smooth, mostly with large surface cells (Fig. 7b, d). *Apodasmia brownii* has longitudinally elongated cells (Fig. 6o) while *Dapsilanthus elatior* has large isodiametric cells (Fig. 7b). *Apodasmia* and *Dapsilanthus* have proved their ability to disperse. *Apodasmia* has one species in each of south-western Australia, south-eastern Australia, New Zealand and Chile. *Dapsilanthus*, with four species, occurs in northern Australia and southeast Asia as far north as Hainan Island.

***Loxocarya* clade:** *Loxocarya* has capsular fruits with both the two carpels mostly developing in *L. albipes*, *L. gigas* and *L. striata*, but only a single carpel developing in *L. cinerea* and *L. magna*. The seeds (Fig. 7i–o) are narrow ellipsoid, compressed, much broader in the axial plane than laterally, with a deep abaxial furrow (deeper towards the micropylar end). The pericarp is rigid and extends apically above the loculus, so that the upper third of the capsule is formed of thick pericarp, distal to the loculus and seed. All species show a distinctive seed surface pattern with lobed cells, separated from the adjoining cells by deep narrow crypts. The inner wall of the ovary is marked with a pattern of narrow ridges matching these crypts. The surface cells of the testa are shallow, broader than deep, with a very thick outer wall.

As in most members of the *Loxocarya* clade, the capsules of *Tremulina* are two-locular. The seeds (Fig. 8a–d) have longitudinal lines of flat angular cells, elongated transversely to the lines. They are surprisingly similar to those of *Dielsia* (Fig. 9l, m) in the *Baloskion* clade. The capsules of *Platychorda* are trilocular and the seeds ellipsoid with an irregular pattern of small convex cells (Fig. 8e, f). Mapping synapomorphies onto a Bayesian consensus cladogram Briggs *et al.* (2014) identified the three-locular capsule as a reversal of an earlier reduction of the number of developed carpels, rather than a plesiomorphic condition.

Chordifex (Figs 8g–o, 9a–k) is characterised by longitudinal lines of convex cells, in some species fused into continuous ridges and in some species exaggerated into sharp blade-like ridges. There is a fine network of intricate narrow ridges between the convexities, or between the ridges, or over the whole surface including the ridges, as in *C. chaunocoleus* (Fig. 9j, k). In the sharp ridges of *C. chaunocoleus*, the ridges are one cell wide, each cell four to six times as high as wide, thick walled with a narrow lumen. In the species with longitudinal ridges, the cells meet in the 'valley' between the ridges and each cell has a convex central portion forming part of a ridge and narrow elongated 'wings' forming part of the slope of a 'valley' between the ridges.

The similarities in seed morphology mostly accord with the groupings in the DNA phylogeny (Briggs *et al.* 2014), for example (among the species represented in the phylogeny) *C. jacksonii* is sister to *C. microcodon* and *C. sinuosus* groups with *C. chaunocoleus*. Before we had DNA data, seed morphology suggested that the eastern Australian species, *C. dimorphus*, *C. fastigiatus*, *C. hookeri* and *C. monocephalus*, might be referred to *Chordifex*, despite a prominent difference from western species of that genus in culm anatomy: the lack of pillar cells (Cutler 1969) in the chlorenchyma. These four eastern species form a clade in the DNA phylogeny suggesting a shared loss of pillar cells, while retaining the longitudinal lines of convex cells characteristic of *Chordifex* seeds.

***Baloskion* clade:** *Baloskion* (Fig. 10e–o) has late-dehiscent capsules that are attached to the subtending glume and dispersed with the glume. The pericarp is thin and papery and, in most members, the seeds are smooth, lacking surface relief, as in *B. pallens*, *B. gracile*, *B. stenocoleum*, *B. tenuiculme* and *B. tetraphyllum* subsp. *meiostachyum*. Surprisingly, the seeds of *B. tetraphyllum* subsp. *tetraphyllum* differ in showing deep longitudinal furrows and convex cells isodiametric in surface view (Fig. 10m–o), unlike the flat cells of *B. tetraphyllum* subsp. *meiostachyum* (Fig. 10l). Our only specimen of subsp. *tetraphyllum* with mature fruits (and numerous seeds) is from Tasmania and we have not been able to check the seed features elsewhere in the range of the species. The other members of the *Baloskion* clade are four monotypic genera, *Dielsia*, *Cytogonidium*, *Tyrbastes* and *Melanostachya* (Figs 9 l–o, 10a–d). In seed morphology they form a disparate assemblage. The rounded convex surface cells of *Cytogonidium* (Fig. 9n, o) are very different from the elongated cells with sinuous walls and low sinuous ridges in *Melanostachya* (Fig. 10c, d) or the lobed cells separated by small deep crypts of *Tyrbastes glaucescens* (Fig. 10a, b). The rows of smooth rectangular cells in *Dielsia* are reminiscent of those in *Tremulina* and very different from other members of the *Baloskion* clade. Most, but not all, populations of *Cytogonidium* are apomictic, producing abundant seed in the absence of male plants.

***Desmocladus* clade:** All members of the *Desmocladus* clade (Figs 11, 13) share the same gynoecial structure. A single carpel develops into a shortly stipitate 1-locular ovary with a single style that is unbranched, often stout and mostly stigmatic. The fruit is indehiscent, a nut, mostly with two pale lateral longitudinal lines marking the carpel margins on the more convex abaxial side and, opposite these, a narrow ridge mostly in line with

the stylar beak. The fruit is shed with a persistent short stipe and tepals if present. The pericarp is hard and bony in *Coleocarya* but is readily split along the adaxial – abaxial plane into two husks. In most species of *Lepidobolus* and *Desmocladus,* and in *Catacolea,* the pericarp is parenchymatous, but in others it is thin and almost membranous (e.g. *L. densus*, *D. laxiflorus* and *D. nodatus*) but it is hard and bony in *D. elongatus* and *D. confertospicatus*. In *D. elongatus,* Fig. 13e shows two pale lateral lines in the ovary region, each of which is double; these appear to represent the carpel margins. On the opposite side of the fruit, which is slightly less convex, is a narrow pale double lateral line.

In the parthenogenetic species in which male plants are unknown, *D. parthenicus* (Fig. 11n–o) and *D. diacolpicus*, the fruit is shed closely enwrapped by a rigid glume. The glume is striate with pale lines (veins) and so closely enwraps the fruit that only its striate nature shows that the diaspore does not consist of the nut alone. The illustration of the 'fruit' of *D. parthenicus* by Pate and Meney (1999 Fig. 1.7B) shows the nut enwrapped by the innermost glume. Both male and female plants are known in *D. glomeratus*, but the fruit is closely enwrapped by the striate innermost glume as in the parthenogenetic species. The nut of *D. glomeratus* is ovoid, c. 1.8 mm long, dark brown with pale lateral lines at the carpel margins, shed enclosed in the innermost glume, with a short (0.7–1 mm) stipe below that glume and also a short stipe between the ovary and glume. The DNA phylogeny placed *D. glomeratus* sister to *D. parthenicus* but the rare *D. diacolpicus* was not sequenced.

Fruit size in the clade varies from 1.5 mm long in *Desmocladus nodatus* to 4–6.3 mm long in *Coleocarya gracilis*. Most have a conical stylar beak persistent on the fruit and in some species (Figs 11j, 13e) the beak is broad, often differentiated in surface texture from the remainder of the fruit, and forms a quarter or more of the fruit. Possibly this development of the fruit above the loculus and seed acts as an elaiosome, attractive to ants as dispersal agents. The seeds are smooth with subangular cells arranged in lines or in an irregular pattern (Fig. 11k–m).

Seed or diaspore mass

Weights for some of the largest and smallest seeds, and for a variety of other Australian restiid seeds and fruits, are given in Table 2. All species of *Alexgeorgea* have large seeds with *A. nitens* at 265 mg and *A. subterranea* at 256 mg. Seeds of other Restionaceae are mostly within the range 0.3 mg to 3 mg, with some fruits (e. g. *Leptocarpus* spp.) lighter than the seeds of other species.

Discussion

Seed morphology proved of limited usefulness in phylogenetic studies of African Restionaceae (Linder 1984). Features of seed shape and ornamentation were described and illustrated by Linder who designated thirteen seed morphology groups among 137 species with dehiscent fruits but was unable 'to establish any polarity for the various characters found in the African taxa'. More recently, Linder and Hardy (2010) included the character of fruit dehiscence but no seed morphology features among the 20 diagnostic or distinctive morphological characters that they used to characterise genera and subgenera of Restioneae. Within Restionoideae they found five separate developments of indehiscent fruits, whereas we noted one development of indehiscent fruits in Anarthriaceae and six in Australian Restionaceae (Fig. 1).

Development, dehiscence and dispersal: The distribution of fruit types in the restiid clade of Poales shows trilocular loculicidal dehiscent capsules as the basic condition. From this there have been increase of carpel number in the Centrolepidoideae (Sokoloff *et al.* 2009) but reduction to bilocular capsules in *Eurychorda* and in the *Loxocarya* and *Baloskion* clades (with a reversal to trilocular in *Platychorda*; Briggs *et al.* 2014), as well as many reductions to one or two developed carpels in the Restionoideae. Reductions to a single developed carpel and indehiscent nut fruit (Fig. 1) are *Empodisma*, *Winifredia,* and the whole of the *Leptocarpus* and *Desmocladus* clades in Leptocarpoideae and in other subfamilies *Aphelia* (Centrolepidoideae) and *Calorophus* (Sporadanthoideae), as well as *Hopkinsia* (Anarthriaceae). Although *Aphelia* is indehiscent (Cooke 1998), it has a membranous pericarp, as in other members of its subfamily, and the carpel margins are readily separable in dried and soaked fruits. From detailed morphological studies, Fomichev *et al.* (2019) concluded that 'Our data suggest that the gynoecium of *Hopkinsia* is unicarpellate (monomerous), as in *Aphelia* (centrolepid clade) whereas gynoecia of some monothecal restiids [such as *Alexgeorgea*] are pseudomonomerous. Thus, we provide further support for the idea that gynoecia with a single fertile ovule probably appeared several times, potentially via different morphological pathways in the evolution of wind-pollinated Poales'.

Linder (1992) investigated which carpel is developed in clades where a single fertile carpel develops, finding some flexibility in whether carpel 2 (the right abaxial) or carpel 3 (left abaxial) develops. In *Apodasmia similis* (referred to as *Leptocarpus similis*) Kircher (1986) showed that carpel 1 (adaxial) or 2 are fertile.

From flowering to seed maturation takes about 10–12 months in many Australian species but ranges from two to three months in *Leptocarpus scoparius* to 15–21 months in *Alexgeorgea* species (Meney *et al.* 1999c). In nut-fruited African species it is reported to take 18 months in *Hypodiscus aristatus* but seven months in *Willdenowia incurvata* (Newton *et al.* 2002).

It is widely found that seeds of indehiscent fruits are not ornamented (although *Hopkinsia* is an exception), so it may be assumed that surface ornamentation has adaptive value in seed disseminules. Likely it may facilitate myrmechory and many restiid species are ant-dispersed in the Cape region and in southwest Australia (Rundel *et al.* 2018). Restiid seeds are often found collected at ant colony sites (Meney *et al.* 1999a, R. Dunn pers. comm.). The pedicel of nut fruit acts as an elaiosome in myrmechorous species in Africa (Bond and Singsby 1983) and probably similarly in *Hopkinsia*, *Desmocladus* and *Hypolaena*.

Studying African species, Caddick and Linder (2002) found that diaspore size is positively correlated with seedling size in the first 4 months of growth and with seedling survival over summer drought following the first growing season. In the Australian Restionaceae there is a great difference in seed mass, with seeds of *Alexgeorgea* more than 10^3 times the mass of the smallest seeds and most species with seed weights in the range 0.3 to 3 mg. Among the smallest seeds are those of the centrolepid clade, mostly ephemeral annuals that avoid drought by their brief growing season.

Fire is an important aspect of the habitats of these species (Pate *et al.* 1999), and many genera include both obligate seeder and resprouter taxa (Meney *et al.* 1997, 1999a, b). Such fire responses have been a feature of African Restionaceae since the Cretaceous (He *et al.* 2016; Litsios *et al.* 2014). Meney *et al.* (1997, 1999a) compared the reproductive potential of a range of Western Australian obligate seeder and resprouter species of Anarthriaceae and Restionaceae, finding that the germinable seed output in some species might be scarcely able to compensate for natural senescence or catastrophic loss of parent populations. Species that regenerate by seed after fire often have more prolific seed set than resprouters and germination in many species is stimulated by fire or smoke.

Indehiscent fruits are mostly shed with tepals and pedicel attached and these act as wings or bear awns or hairs that may aid dispersal. In some *Lepidobolus* species the glumes fall with the fruit held in the glume keel (Fig. 13a). Fruits of *Baloskion* are late-dehiscent capsules dispersed with the fruit and floral parts attached to a glume—which acts as a wing—but retain two loculi and two styles. This condition was illustrated for *Baloskion tetraphyllum* in the protologue of *Restio tetraphyllus* (Labillardière 1806: tab. 227). The seeds are mostly smooth but *B. tetraphyllum* subsp. *tetraphyllum* show some ornamentation (Fig. 10m–o).

Diaspore mass: Caddick and Linder (2002) contrasted the alternative strategies for reproduction and dispersal in African Restionaceae with large and small diaspores. Only obligate seeder species were included in their study, since resprouting species are less evolutionarily constrained by diaspore characteristics. They found a negative correlation between diaspore size and diaspore number, indicating a trade-off between these variables in the allocation of reproductive resources. They also found that large woody nuts produced in small numbers have well-protected diaspores with large resources to develop large seedlings that survive summer drought. The alternative strategy of small seeds or soft nutlets produced in large numbers are poorly protected diaspores with small resources that develop small seedlings and have high mortality during summer drought. The majority of Australian Restionaceae occur in the south of Western Australia on low-nutrient soils in seasonally moist or wet sites (winter wet, summer dry) in a mediterranean climate of summer drought similar to that experienced by the South African species. We did not investigate the way in which seed features are related to habitat in the Australian taxa, but field observations suggested that a similar relationship exists. For example, the larger-fruited *Hypolaena* and *Desmocladus* are mostly in drier habitats than *Leptocarpus,* although the larger-seeded *Anarthria* and *Loxocarya* are not in notably drier sites than the smaller-seeded *Chordifex*. The species of the genus with the largest fruits, *Alexgeorgea*, range from sub-arid (*A. subterranean*) to seasonally waterlogged sites in a more mesic region (*A. ganopoda*) and the large fruit size is presumably associated with their development below ground, rather than with climatic factors. Such development may be an extreme adaptation to avoid fire and predation. The seeds of *Alexgeorgea ganopoda*, at 0.605 g (Meney *et al.* 1990), the largest in Restionaceae, have over 1000 times the mass of the smallest seeds we report in *Centrolepis fascicularis,* with most species within the range 0.3–3 mg. The smallest seeds are in perennials in regions with relatively reliable rainfall, such as some *Leptocarpus* species, or ephemeral annuals that avoid drought by their brief growing season, as in most *Centrolepis* and *Aphelia* species. The largest fruit among African species reported by Caddick and Linder (2002) is *Cannomois grandis* at 0.303 g. Our sampling was not comprehensive and the findings (Table 2) are subject to error since often few seeds or fruits were available and it was not feasible to test for seed maturity although, in nut fruited species, 'early hardening of the ovary wall gives the impression that seed is mature' (Newton *et al.* 2002).

Seed surface patterns: The surface features illustrated here do not show patterns that are indicative of the relationships shown in the DNA-based phylogeny. No features have been hypothesised as plesiomorphic states. The basal branches of the restiid clade have diverse seed surface features: longitudinal lines of more or less convex cells in *Anarthria*, small cells with a concave surface and spicules at the cell corners in *Lyginia*, convex polygonal cells in *Hopkinsia*, a prominent intricate network of narrow ridges over the cells (tertiary structure) in *Sporadanthus* and some of *Lepyrodia*, longitudinal ridges in some of the centrolepid clade.

Some genera have distinctive seed features, such as *Chordifex* with longitudinal lines of convex cells, sometimes fused into ridges or *Loxocarya* with a longitudinal furrow and a distinctive surface cell shape and deep clefts between the cells. A very distinctive surface pattern, rows of cells that are flat, parallelogram-shaped and elongated transversely to the row, is shared by *Dielsia* and *Tremulina* whose relationships suggest that this is not a synapomorphy.

Fossil fruits referred to Restionaceae: Dettmann and Clifford (2000) assigned small, indehiscent unilocular fruits with a single pendulous orthotropous seed that has a structured micropylar cap from late Eocene or early Oligocene sediments of central eastern Queensland to the fossil genus *Restiocarpum*, describing five species of *Restiocarpum* from those sediments. The generic description noted 'the fruits are assumed to be indehiscent as there is no indication of dehiscence structures on their walls, which are usually preserved intact' and 'Fruit wall single-layered … Seed wall single-layered except about the micropyle, where a multicellular cone is developed' and that the ellipsoidal to ovoid fruit tapers apically 'to a stigma of one to three styluli'. The apical region of the fruit is well preserved in specimens they examined of four of the species of *Restiocarpum* and the styluli are slight rounded projections, described as 40 μm long in *R. verrucatum* and 110 μm long in *R. latericum*.

Smith *et al.* (2010) accepted *Restiocarpum* as probably belonging to Restionaceae, in the absence of suggestions that they belong to another family. They noted that 'More work is needed to document detailed anatomical and morphological features of monocots, especially for reproductive material that can provide a suite of morphological characters'. All modern Restionaceae have well-developed styles and this would appear to be an obstacle to matching *Restiocarpum* with Restionaceae. Styles in the family include: the three separate styles of *Sporadanthus* and *Calorophus* arising at distal corners of the fruit apex; in Centrolepidoideae the long slender styles of individual carpels of *Aphelia* and *Centrolepis* or the long but partially fused styles of *Gaimardia* (Sokoloff *et. al.* 2015); the long styles of the *Leptocarpus* clade, mostly fused for about half their length with three long stigmatic branches; and the stout, almost wholly stigmatic styles of the *Desmocladus* clade. But nowhere in the restiid clade are there gynoecia and fruit with extremely short styles and minute styluli. Particularly in *R. tesselatum* (Dettmann & Clifford 2000, Plate VI, figs 1 and 2) the very short, rounded protuberances appear well preserved and are impossible to interpret as broken styles, very different from the elongated styles of all modern Restionaceae and Anarthriaceae. Apart from the major difference in the stylar region, only *Leptocarpus*, *Apodasmia*, *Chaetanthus, Dapsilanthus* and the centrolepid clade have pericarps as thin and membranous as *Restiocarpum*. Similarities to Restionaceae in other features mentioned by Dettmann and Clifford are not convincing to us in matching the fossil fruits to any living taxa or clades.

Dettmann and Clifford (2000) noted the presence of *Milfordia* pollen in the same deposits as *Restiocarpum* and that the source community of the deposits had similarities to 'restiad swamps of present day Wallum (swamp heathland) vegetation which is extensively developed along the Queensland coast'. *Milfordia* pollen was widely identified with modern Restionaceae (e.g. Ladd 1977, Krutzsch 1989) and described from a great range of sites, including ones in Europe and north America, far outside the present or likely range of Restionaceae, an almost exclusively southern hemisphere family. Linder (1987) and Linder *et al.* (1998) concluded that there are no diagnostic features linking the *Milfordia* pollen-type (graminoid pollen) to Restionaceae. Instead, this fossil pollen type could equally belong in Flagellariaceae (which does currently occur in northern Australia), Joinvilleaceae (currently southeast Asia and the Pacific islands) or Anarthriaceae (currently southwest Australia only). *Restiocarpum* fruits show no notable similarities to fruits of Flagellariaceae (3-locular drupes), Joinvilleaceae (1–3-seeded drupes) or Anarthriaceae (3-locular capsules or small 1-seeded nuts with a woody pericarp and stout style). Four major types have been recognised in modern restiid pollen (Linder and Ferguson 1985), with the graminoid type in Anarthriaceae and the Australian restioid and centrolepidoid types present in living Australian Restionaceae (as recognised here). Pollen similar to that of modern Australian Restionaceae occurs in Oligocene deposits from southeast Australia (Martin 1973) and from the Miocene onwards in New Zealand (Conran *et al.* 2015). We see no adequate evidence to link *Restiocarpum*, or the *Milfordia* pollen that occurs with it, to Restionaceae.

The circumscription of Restionaceae: Restionaceae s.str. or Restionaceae s. lat.? To recognise Anarthriaceae? Centrolepidoideae or Centrolepidaceae?

There are currently varied opinions on whether to recognise Anarthriaceae separate from Restionaceae (Briggs *et al.* 2014, Givnish *et al.* 2018) or to include the *Anarthria* clade in Restionaceae (APG IV 2016, Fomichev *et*

al. 2019), and whether the centrolepid clade should be included in Restionaceae as Centrolepidoideae (Briggs *et al.* 2014) or treated as Centrolepidaceae (Sokoloff *et al.* 2015). As noted above, Anarthriaceae as recognised here are extraordinarily diverse in their seed and fruit types: *Hopkinsia* having woody indehiscent fruits with a fleshy outer pericarp layer; *Lyginia* having dehiscent capsules and seeds with a unique circular flange and surface ornamentation of spicules at the corners of surface cells. *Anarthria* also has dehiscent capsules and seeds with a pattern of longitudinal lines of cells and a secondary pattern of striations that is different in detail from the ornamentation of seeds of any genus of Restionaceae, but not outside the range of variation within Restionaceae. The seeds of the centrolepid genera, *Gaimardia*, *Aphelia* and *Centrolepis*, range from smooth to longitudinally furrowed and are mostly smaller than those of other restiid genera. We consider that, not surprisingly, seed morphology does not contribute to determining an appropriate circumscription of Restionaceae.

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Grevillea manglesii (Proteaceae: Grevilleoideae: Hakeinae) revisited

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Abstract

The correct citation for *Grevillea manglesii* (Proteaceae) is *G. manglesii* Pépin (1838). A neotype is here selected from among historic collections, now at Paris (P). Should the minimal description provided by Pépin be successfully challenged as inadequate, the name would not change but the revised authority would be *Grevillea manglesii* (Graham) A.Baumann and N.Baumann (1843). The origins and complex taxonomic and horticultural history of *G. manglesii* and its synonyms *Manglesia glabrata* Lindl., *Anadenia manglesii* Graham, *Grevillea manglesii* Hort., *Manglesia trilobata* Hort. ex Ettingsh., and *Manglesia cuneata* Endl. are outlined and discussed, together with new insights discerned from James Mangles' unpublished Letter Books. The important role of Captain James Mangles R.N. to the botany and horticulture of *Grevillea manglesii* is reviewed and historical errors are corrected. *Manglesia glabrata* Lindl. is lectotypified. *G. ornithopoda* Meisn. is reinstated at specific rank and *G. dissectifolia* (McGill.) Olde is published as a new combination. Both are phenetically diagnosable without intergrades and occur in discrete populations that sometimes overlap the distribution of related species.

Introduction

In May 1839, Stephan L. Endlicher (1839: 25) erected the genus *Manglesia*, in which he described two species, *Manglesia tridentifera* Endl. and *M. vestita* Endl. Endlicher not only named his new genus after the English horticulturist brothers, James and Robert Mangles, but acknowledged them as the source of numerous plants from south-west 'New Holland' that 'already adorn our gardens'. From 1840, Endlicher was the director of the Botanic Garden at Vienna (*Hortus Botanicus Vindobonensis*) and was also Professor of Botany at the University of Vienna to which the Botanic Garden was attached (Rompel 1913). In the years leading up to his important academic appointments, Endlicher (1837, 1838, 1839) described many species of Australian Flora, using both the dried gatherings of various collectors and living plants in cultivation, of which the most important was probably Baron Karl von Hügel (1795–1870). Von Hügel had not only collected specimens and seeds in Western Australia between 1833–1834 but maintained a large garden at Hietzing, near Vienna, Austria, famous for its beauty and variety of cultivated plants. There he not only grew many species of Australian plants from mainly imported seeds between 1824–1848 (Lindley 1839–40, Peintner 1841, Loudon 1842) but he also exported live plants over large parts of Europe (Jacques 1843, Planchon 1858). '*Colitur in horto Hügeliano*' [It is cultivated in von Hugel's garden] is a familiar sentence in many of Endlicher's species' treatments of Australian plants.

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In his discussion of the genus *Manglesia*, Endlicher (1839: 25) also mentioned a third species, *Manglesia cuneata* Endl., to which he referred *Grevillea manglesii* 'Hortul.' as a synonym. (The term 'Hortul.' or 'Hort.' is an abbreviation of the Latin *hortulanorum*, of gardeners, used with epithets given by horticulturists, often to plants that have not been formally described). Although Endlicher referred to *Manglesia cuneata* as if it had already been published, no earlier description has been found. The name came into accepted use, particularly in Central Europe, and there are two undated specimens of *G. manglesii* (P750707, P750708) ex *Hort. Bot. Vindobonensis* labelled *Manglesia cuneata* Endlicher that serve to remind us of the acceptance of this name at the time and for several decades later (e.g. Ettingshausen 1858: 255). However, as McGillivray and Makinson (1993: 428) pointed out, 'the diagnostic and descriptive data included in the same paragraph as the name *Manglesia cuneata* serve only to distinguish the genus *Manglesia* from other taxa.' Endlicher (1842a: 287) later asserted the priority of *Manglesia cuneata* over *M. glabrata* in a catalogue of the plants growing in the *Hortus Vindobonensis* but again there failed to distinguish it. Thus, *Manglesia cuneata* is affirmed as *nomen nudum* and the subsequent proposal by Druce (1917: 625) to cite it as the basionym of the supposed combination *Grevillea cuneata* (Endl.) Druce is also a *nomen nudum* and equally insupportable. In any case the combination *Grevillea cuneata* was occupied by that time because Jacques (1843: 191) had validly published the name in reference to a related species with pubescent branches and leaves, probably *Grevillea vestita* (Endl.) Meisn., and without citing Endlicher's name as basionym. *Grevillea cuneata* Jacques is one of seven species or varieties of shrubs, originally from New Holland, sent from Vienna by von Hügel to the residence of M. Martine, a flower gardener, Rue des Bourguignons, Paris. The application of Jacques' name is uncertain in the absence of a cited type but it certainly does not apply to *Manglesia cuneata* Endl., a glabrous shrub cited by Endlicher with *G. manglesii* Hort. as synonym.

It is not stated in Endlicher's 1839 work where specimens of *Grevillea manglesii* Hort. were consulted or collected but the *Hortus Botanicus Vindobonensis* at Vienna, noted as a place of its cultivation only a few years later by Endlicher (1842a), would be a reasonable starting point. Endlicher might also have seen it in the garden of von Hügel at Hietzing. *Grevillea manglesii* was among the Australian plants relocated to the glass-houses of Prince Anatole de Démidoff at San Donato near Firenze (Florence) by von Hügel between 1853 and 1856 (Planchon 1858: viii). At Schönbrunn Palace, home of the Habsburgs, an important collection of Australian plants was also being accumulated and it was there that Ettingshausen (1858) illustrated and described *Manglesia trilobata* Hort. ex Ettingsh., likely conspecific with *G. manglesii* (*fide* Olde 2017: 310). The nurserymen S. and J. Rinz (1838: 27) of Frankfurt also listed '*Grevillea Manglesii*' for sale at 12 fl. per plant. Almost certainly, the plant came originally from England, where it had been raised from seed, and where, from 1837, it was known by the same name, *Grevillea manglesii* Hort. (Graham 1839).

In June 1839, Robert Graham (1839: 189) formally described a plant, sent to him as *Grevillea manglesii* Hort., using a cultivated plant flowering in Edinburgh Botanic Garden, Scotland, naming it *Anadenia manglesii*. Robert Brown, at that time the leading Proteaceae taxonomist, would have strongly disapproved, having already written (1830: 21) that, as with *Grevillea anethifolia*, the presence of a semi-annular hypogynous gland [or nectary] required its inclusion in *Grevillea,* 'as one diverse genus'. Graham noted that it had been sent to him by the nurseryman Mr. Lowe [sic] of the Clapton Nursery, in 1837, 'under the name of *Grevillea manglesii*'. It seems likely that Low had bestowed the specific epithet in honour of one of the Mangles brothers, reflecting perhaps also the source of his plants. W.J. Hooker (1841) published an illustrated treatment of Graham's *Anadenia manglesii,* repeating Graham's diagnosis, with slight modifications, and a much abbreviated portion of the protologue. For many years, indeed until relatively recently, it was mistakenly thought that Graham's description was first published in Hooker's work, leading to a misunderstanding about the original date of Graham's publication and consequent errors in nomenclatural priority and correct authority. McGillivray and Makinson (1993: 427) even considered (but did not cite) Hooker's plate as a suitable type, no doubt because the treatment by Graham in Hooker was also thought by them, and indeed even by Meisner (1845: 549), to be the first. However, Hooker's illustration was based on a specimen of unknown type status in his own herbarium, according to the title page (Hooker 1841) and not the plant growing in Scotland.

As early as 1838, even before the genus *Manglesia* had been published, John Lindley (1799–1865), a leading English botanist, became aware of Endlicher's intention. The information probably came from correspondence with Endlicher (now lost, see Riedl-Dorn 2019) or possibly from Robert Brown or George Bentham with whom Endlicher is known to have corresponded (Rompel 1913). After borrowing specimens from his friend Captain James Mangles R.N.(*q.v.*) which had been sent by James Drummond (*q.v.*) and others, Lindley (1838c) wrote in part 'The Swan River collection is much more interesting than the other and contains many things quite new to me. I want to find among them something good enough to be created a Manglesia and no doubt I shall succeed; it would be my frontispiece'. On 15 September, Lindley (1838d) again wrote to Mangles 'There are many new genera, as you will see; but I do not find one quite so pretty as I could wish for Manglesia. This however we shall be able to settle by and by. In the meanwhile I am anxious for materials as I am bent upon

publishing 'A view of the botany of the Swan River Colony'. It is clear from these two extracts that none of the Drummond specimens that Lindley had seen up until then was suitable for description as *Manglesia*. The collections of James Drummond, to which Lindley referred, comprised a specimen book 'choke full' of pressed plants attached to numbered pages, and about 60 (?100) unnumbered specimens of Proteaceae in a separate parcel sent via the *Hero* (Drummond 1837, 1838). We can also gather from this correspondence that, at that time, Lindley was unaware of the horticultural presence in England of *Grevillea manglesii* Hort., or if he was, did not recognise its connection to *Manglesia*.

However, around 5000 unsorted Drummond specimens capable of division into 10 sets of 500, which had mainly been collected in 1837 (Drummond 1839, Erickson 1969: 35–6) and sent in November 1838, arriving at Margate from Australia in the *Joshua Carroll* on 21 April 1839 (Lemson 2015), changed all that. The *Joshua Carroll* also carried the first consignment of specimens from Georgiana Molloy (1805–1843), a consignment of live plants from near Perth, packed by Captain Richard Goldsmith Meares (1780–1862) and seeds from Lady Ellen Stirling (Lady Stirling 1839). Drummond (1838a) also sent £15 worth of seeds to Low on the *Joshua Carroll* in response to an order sent in 1837 (Drummond 1837). The value of this order in today's currency would be AUD$2500–4000. By 2 July 1841, trade between Low and Drummond had expanded to the degree that an agreement to supply seeds and bulbs was entered 'to a certain annual amount' (Drummond 1842b: 215).

The specimens and plant cargo were consigned to Captain James Mangles R.N. but soon ended up in Lindley's hands. Mangles had originally agreed to handle Drummond's specimens and to aid his attempts to find buyers for them, so that he (Drummond) could spend his whole time in the bush collecting natural history specimens, including plants and insects. For a number of reasons outlined by Erickson (1969) Mangles soon backed away from this agreement. In addition, Mangles (1839: 7) stated that he was 'totally ignorant of botany' apart from which he was not enjoying good health at this time, suffering from 'a protracted illness, accompanied with intervals of fluctuating debility and lowness of spirits'.

Lindley (1840b) requested George Bentham to divide Drummond's specimens from the *Joshua Carroll* into sets and to begin the task of finding and distributing them to potential buyers. 'I wish to present Mr [Robert] Brown with a full collection to be placed in the Linnaean Herbarium or rather the Herbarium of the Linnean Society. I send you specimens of upwards of 100 Proteaceae, about 50 Orchidea and about 30 Stylidiums' (Drummond 1838a). Brown received at least some of his specimens in July 1839 (see *Manglesia glabrata*, list of isolectotypes, below). Lindley also secured for himself the free right to one of the sets (Drummond 1836), most of which are now in Lindley's herbarium at CGE (Gardiner 2018). Another party interested in Drummond's specimens and correspondence was William Jackson Hooker (1785–1865), soon to be appointed the first full-time director of Kew, who wrote to Drummond in 1839 asking him specifically to make collections for him, a request fulfilled initially in 1842, from which time Drummond's First Collection and numbering *sensu* Hooker dates. These collections subsequently also got confused until they were sorted by Mr Richard Kippist (1812–1882), librarian of the Linnean Society (Meisner 1852: 181).

In the third part of *A sketch of the vegetation of the Swan River Colony*, Lindley (1840a: xxxvii n.183) published the name *Manglesia glabrata,* noting there his support for Endlicher's generic concept (see Olde 2020) but not linking the name with any synonyms. In none of the correspondence or published literature seen is there any evidence that Lindley was aware of *Grevillea manglesii* Hort. or Graham's earlier description of *Anadenia manglesii* prior to publication. However, even if he were, he could have been operating under the existing 'Kew Rule', as Mabberley (2020) has pointed out, whereby the first name to be used in any particular genus was considered to have priority in that genus over the first published specific name, if that epithet had been published in another genus. McGillivray and Makinson (1993: 427) nominated, as holotype of *Manglesia glabrata,* a specimen collected by James Drummond, presumed here, for reasons already stated, to be from the consignment of unsorted and unnumbered specimens sent in the *Joshua Carroll,* and which arrived in 1839.

In appreciation of the specimen books, correspondence and specimens in sets loaned or given by Mangles which he used so extensively, Lindley (1840e) wrote to Mangles on 14 January 1840. 'With this I have the pleasure to enclose for you a nice bit of "*Manglesia vestita*" and a live branch of "*Manglesia glabrata*" which latter your brother gave us a plant of - the other I have never seen - *Manglesia glabrata* is the only species in this country, so far as I know. I am waiting impatiently for a copy of my Appendix for you from the binder…'. Stafleu and Cowan (1981) state that Lindley's '*Sketch*' , issued as an Appendix to Volume 23 of Edwards' *Botanical Register*, was published in three parts, two respectively in November and December 1839, the final and third part on 1 January 1840. However, this letter from Lindley suggests a slightly later date, after 14 January 1840, for effective publication of the third part. On 4 February 1840, as recorded in the minutes of an Ordinary Meeting of the Horticultural Society of London (The Secretary 1840: 126), of which Lindley was Assistant Secretary and indeed, according to its historian Harold Fletcher (Fletcher 1969), its backbone and greatest servant, *Manglesia glabrata*, 'a new and pretty shrub from the Swan river' was exhibited with other flowers from the Society's own garden at Chiswick, courtesy of the donation by Robert Mangles, already alluded to (Lindley 1840e).

Among the Drummond specimens that arrived in Lindley's herbarium in 1839 was a specimen of *Manglesia vestita* (CGE13286) from which, it must be presumed, that Lindley either detached a piece or a duplicate, and gave it to Mangles. Even so, soon after Endlicher published the name *Manglesia vestita*, the current concept of that species was established and continued in horticultural catalogues, contrary to doubts raised by McGillivray and Makinson (1993: 447). Although Lindley, by 1840, had become aware that *Grevillea manglesii* Hort. and *Manglesia glabrata* were synonymous, another specimen of *Manglesia* sent by Drummond in 1839 was overlooked for description by Lindley (*M. vestita* var. *angustata* Meisn., CGE13287). Drummond (1842c) summarised the situation for readers of the *Inquirer* 'Of *Manglesia*, a new genus lately separated from *Grevillea*, we have 7 or 8 species; I believe all the known species of the genus are from Swan River; the finest of them, the *G. Tridentifera* [sic], now in full flower in the York and Toodyay districts, is called by the settlers the Swan River Hawthorn, as, from the number of its snow-white flowers, and the size and shape of the plant, it bears some resemblance at a distance to the favourite English hawthorn.' [Perhaps, in the dark, with the light behind!] The name *Grevillea paniculata* Meisn., a glabrous shrub, has today replaced the name *G. tridentifera* (Endl.) Meisn., although it had not been published when Drummond was writing. Indeed, *Manglesia* was not formally synonymised under *Grevillea* until 1845 (Meisner 1845). Endlicher's extensive description of *Manglesia tridentifera* does not unambiguously point to any one species, and because the type specimen, which was collected by John Septimus Roe between 'Swan-River and King George's Sound' is missing, despite searches at numerous European herbaria including W, it cannot be neotypified with confidence, and is therefore treated as a name of uncertain application.

Lindley mentioned very few specimens in the 283 species which he described in the '*Sketch*' that could be cited as types. However, he made clear in the introduction (Lindley 1839a: ii) and in a pamphlet circulated and published in several places (Lindley 1840b) as to what collectors and specimens he owed the greatest debt. Typification of his 283 species has mostly proceeded on the basis of this information. The specimens which Lindley championed both there and in the text were mainly those collected by James Drummond. Other acknowledgements from the introductory section (see Part 1) included James Mangles himself, Robert Mangles, Andrew Toward (fl. 1816–1840) gardener to the Duchess of Gloucester, and Nathaniel B. Ward (1791–1868), inventor of the Wardian case. Garden specimens of Australian plants raised mostly from seeds by Andrew Toward and mounted in specimen books (Loudon 1828b) presumably comprised the specimens made available to Lindley. Some of Toward's specimens are now at CGE and a specimen of *Manglesia glabrata,* presumably a specimen raised originally from seed by Hugh Low or Robert Mangles, is mounted with the lectotype of that species. Ward's contribution seems to be that he made available to Lindley Drummond specimens loaned to him by Mangles (Ward 1838).

Specimens supplied by other collectors were not acknowledged separately by Lindley. These include specimens collected by ship's surgeon Alexander Collie (1793–1835) one of which was cited specifically by Lindley (1840a: li) in his description of *Caladenia marginata*. The specimen *Preiss* 445 was also used in the description of *Aristida aristata* by Lindley (1839b: 25). Fifty three specimens supplied by Ludwig Preiss (1811–1883) and sent to Mangles by G.F. Moore were distributed to Lindley among others (J. Mangles undated a). Although Lindley was aware and impressed by Georgiana Molloy's specimens, and noted (1839c) that 'many of the best are quite new' he failed to acknowledge her anywhere. The omission has been rectified in several lectotypifications subsequently and Patrick (2005) lists the type status of many other Molloy specimens in relation to species described by Lindley, both in the '*Sketch*' and elsewhere.

Linking the synonyms

The botanical nomenclator Ernst Gottlieb von Steudel (1840: 83) first linked the formally published name *Anadenia manglesii* Graham with *Manglesia cuneata* Endl., as Mabberley (2001) noted, thereby indirectly linking the name *Grevillea manglesii* Hort. Endlicher (1842a: 287) also indicated that synonyms of *Manglesia cuneata* included *Manglesia glabrata* Lindl. and *Grevillea manglesii* Hortul., a more direct linkage, but one in which Endlicher prioritised *Manglesia* over *Grevillea* and did not cite *Anadenia manglesii*. Endlicher (1842b: 37) reported also that Brown said that the genus *Anadenia* should be suppressed and that even *Manglesia* could not be tolerated.

When Meisner (1845: 534) synonymised *Anadenia*, *Manglesia* and other genera under *Grevillea* R.Br. ex Knight, he recognised *Grevillea glabrata* (Lindl.) Meisn. as the name with the greatest claim to priority (p. 549). Although he noted Endlicher's *Manglesia cuneata* as an earlier, 'validly' published name, he elected to treat it as a synonym on the basis that Lindley's treatment was more convincing, 'quia magis distinctivum'. He also cited as synonym *Anadenia manglesii* Graham in Hooker (1841), postdating Lindley's *M. glabrata,* instead of Graham's earlier publication in 1839, certain knowledge of which actually did not re-emerge into the light until *c.* 1992–3. Therefore, the combination *Grevillea manglesii* with the correctly dated basionym was not made by Meisner. Meisner (1845, 1856) cited unnumbered Drummond specimens collected between 1837 and 1839 as 'Coll. 1'. However, *Drummond* 'Coll. 1' usually refers to numbered specimens gathered for W.J. Hooker

from 1842. It is well to be aware of these differences between William Hooker and Meisner in the citation of Drummond's early specimens by Meisner.

Mabberley (1990: 274) noted that Planchon (1858: 96) accepted the name *Grevillea manglesii*, but the significance of this with respect to Graham's publication was still unrealised and the authority Hort. ex Planch. was proposed by him. In 1992, Graham's original (1839) publication of *Anadenia manglesii* was recognised and McGillivray (1993: 427), unaware of Mabberley's discovery, incorrectly altered the previously accepted name from *Grevillea glabrata* to the isonym *Grevillea manglesii* (Graham) McGill., and proposed as neotype a cultivated specimen (E00438973). Independent of Mabberley (1990), whose paper they had not seen, Olde and Marriott (1995: 14) accepted the name and authority of *Grevillea manglesii* (Graham) Planch. because Planchon had cited the validly published name *Manglesia glabrata* Lindl. as a synonym. Planchon did not cite *Anadenia manglesii* Graham in synonymy, though the name had already been linked by Meisner (1845).

Makinson (2000: 421) in the *Flora of Australia* also took account of Planchon's name, which by then was incorporated in *Index Kewensis*. Although warning that there might be an earlier valid usage of the binomial in other horticultural texts, Mabberley (2001) elaborated on the validity of Planchon's combination. He pointed out that *Grevillea glabrata* (Lindl.) Meisn. was effectively illegitimate because of the inclusion of *Anadenia manglesii* in synonymy. In proposing the revised authority (Graham) Planch., he was unaware that Olde and Marriott (1995) had already independently adopted it.

In connection with work for a paper on competing German botanical texts (Mabberley 2020), David Mabberley (pers. comm. 1 November 2020) communicated an even earlier valid publication of *Grevillea manglesii*. An extensive catalogue of plants issued in Dresden by Traugott Jacob Seidel (Seydel) (1775–1858), a member of a famous horticultural dynasty, 'Pflanzen-Catalog für das Jahr 1846', includes 'Grevillea Manglesii (Manglesia cuneata)' among the plants for sale. So far, despite the concerted efforts of Clemens Wimmer (Potsdam) and Dr. Stefan Dressler (FR), no copy of the original catalogue has been found, but it was reprinted by Mettler and Otto in a horticultural journal the same year. The possibility of an even earlier Seidel work or other publication validating the combination can still not be ruled out.

Ongoing searches of early horticultural catalogues by the author have recently revealed that 'Grevillea Manglesii' was first listed for sale in the 1838–39 catalogue of S. and J. Rinz of Frankfurt, Germany where on P.27 it was recorded, *nomen nudum,* with 13 other species of *Grevillea*. However, more significantly, in the catalogue of A. and N. Baumann (1843–44: 27), 'Grevillea Manglesii Hort.' and its synonym 'Manglesia cuneata Endl.' were listed together in the correct order, thus providing the necessary linkage to date for the earliest legitimate combination of the name *Grevillea manglesii*. Augustin and Napoléon Baumann, two younger brothers of Joseph Baumann, from Bollwiller and Mulhouse, Upper-Rhine (France) issued their first nursery catalogue in 1843–44 under their own name. At 33 pages, the catalogue greatly expanded the 14-page catalogue of John Baumann and Sons in which *G. manglesii* was listed *nomen nudum* (1841–42: 11). It seems clear from a note on the last page by Joseph-Bernard (Jos.-B.) Baumann, the oldest brother, and foreign corresponding member of the Horticultural Society of London from 1826, that 'la société des frères Baumann' had recently and probably unhappily dissolved 'after 40 years work and experience in the old business which I founded and led', and that Joseph Baumann and his sons, Alexandre and Eugène, would henceforward trade under the name 'Jos. Baumann et Fils'. His brothers Augustin and Napoléon would henceforward operate a separate business and it is in their first catalogue that the validating linkage was made.

James Mangles

Captain James Mangles RN, FRS (1786–1867) was pivotal to the introduction of most Australian plants to English horticulture and botanical science during the 1830s. A biography by Richards (2002: 398) summarises his life well but incorrectly states that the pioneering settler George Mangles was his brother. James Mangles was a retired English naval captain, noted traveller, and friend of John Lindley and J.C. Loudon (1783–1843), the garden writer, whom he met and accompanied from Genova to Firenze in July 1819. According to Loudon's wife (J.W. Loudon 1845: xxvii) Mangles, together with his friend and ultimately brother-in-law Charles Irby RN, travelled with Loudon along the shores of the Mediterranean, 'leaving Genoa [Genova] on the 6th July in a felucca for Leghorn [Livorno], where they arrived on the 8th, and thence proceeded through Pisa to Florence [Firenze]' looking at gardens along the way. Thereafter, Mangles formed a life-long friendship with the Loudons, husband and wife, and his deep interest in horticulture included an interest in public garden design and amenity that appears to date from that time. Earlier in the same year, at Marseilles, he met and formed a strong friendship with James Stirling, then a naval confrère (Statham-Drew 2003: 23). Subsequently, following an invitation from Mangles to visit 'Woodbridge' near Guildford, Surrey, the home of Mangles' then more famous uncle, James Mangles MP (1768–1838), Stirling met his future wife, Ellen, then at the tender age of 13, and for whom he developed first a deep infatuation and subsequently an abiding love. James Stirling and Ellen Mangles eventually married one week before her sixteenth birthday, thereby accumulating a

debt to James Mangles for his part in occasioning their meeting and their apparently long happy life together subsequently which yielded 11 children (de Mouncey 1930). Stirling's leadership of the Pinjarra massacre of the Binjareb Aboriginal people on 28 October 1834 has blackened the memory of his other achievements.

Between 1835 and 1838, Mangles was the main distributor of seeds and dried specimens flowing from Swan River to English horticulturists. Much of what we know about him derives from unpublished correspondence held in the J. S. Battye Library, Perth, known as Mangles' Letter Books. The Letter Books contain mainly inward correspondence relevant to Mangles' important but honorary role as importer and distributor of seeds, especially from Australia. It is worth noting at this point that the conserved correspondence is pseudo-original, letters, or sometimes only excerpts, neatly copied by the hands of at least two anonymous transcribers, and the detail combined on numbered pages, now scanned onto microfilm, the pages loosely grouped by date or sender, but not well indexed or arranged. Although there is little by way of original communication emanating from Mangles, much can be inferred from replies to him.

The accumulation of this correspondence occurred after Mangles had returned from the Swan River colony, where he had arrived on 25 April 1831 on the *Atwick* with its complement of 13 passengers (J.S. Battye Library). He was then 45 years old, unmarried, and childless, as he remained all his life, contrary to a mis-statement by Coats (1973) that he had a son who outlived him. The sole beneficiary of his substantial will was his housekeeper (Kirwan 1936, Statham-Drew 2003). In a letter dated 5 December 1830 to the Admiralty seeking two years' leave, Mangles (1830) gave as his reason 'in order to explore that country' (Statham-Drew 2003: p. 575). The main real purpose seems to have been to investigate shipping opportunities for the Mangles family interests, and to visit his cousins George Mangles and Ellen Stirling and his friend James Stirling, her husband and by then, Lt.-Governor of the Swan River colony. Mangles apparently lived with them during his stay and supported his pregnant cousin who was undergoing difficulties at the time.

According to Drummond (1843) Mangles arrived at Fremantle bearing four cultivars of olive that were planted in the Government Garden and propagated by 'laying' in 1832. The ongoing acknowledgement for this first introduction to Western Australia bears witness to Mangles' foresight and thoughtfulness. Erickson (1969: 17) states that Mangles was in Western Australia for three months. Plant specimens at B, BM, CGE, GH and K (*fide* Orchard 1999 in part) attest to his activities and interests while resident there. Cameron (2006: 29) records that on June 22 1831 George Fletcher Moore (1798–1886) went on a 'botanising excursion with Mrs Stirling, Mrs McD., Capt. Mangles and Mr Dale (Lieut.)' and that (*ibid.*: 32) on July 10 Moore 'gathered many varieties of beautiful plants and shrubs for Capt. Mangles.' Moore (1884: 50) notes that on July 21 he also gave Mangles 'specimens of flowering shrubs besides a bottle full of snakes, lizards and scorpions', thereby confirming Mangles' botanical and natural history interests. A specimen of *Grevillea bipinnatifida* R.Br. collected on 12 August 1831 (BM915609), records his presence four months after his arrival, and is the latest dated evidence, though other specimens were also collected in 'August'. An undated specimen of *Grevillea excelsior* Diels (CGE05816) from beyond the Perth region might possibly have been given to him by another person as there is no evidence that he went exploring. Although he undertook local trips up the Swan River by boat with friends (Moore 1884), this area is well outside the known distribution of that species. According to Chate (1867), Moore himself accompanied Ensign Robert Dale to the York District in September 1831 and either he or Dale or even Stirling himself, may, I here speculate without evidence, have been the source of this specimen.

These notes represent a refutation of a printed note appended to herbarium sheets of many Mangles' specimens by Ms J.E. Tonkin (ABLO 2006–2007) variously dated in 2007, who asserts, in part and without supporting corroboration, that there is 'no evidence' that Mangles collected plants during his stay. This conclusion stands in stark contrast to the evidence presented here. There are over 20 specimens attributed to Mangles as collector with both printed and handwritten labels at B, BM, CGE, GH, K (*fide* Orchard 1999 in part). The printed labels date from the time when Mangles was active, apparently printed by Hooker, and are similar to those used for Drummond's specimens, about which no similar doubts about authenticity are raised. Equally there is also no evidence that the specimens of others were arrogated by him, as also suggested by Tonkin in the appended note, except to say that there are at least 77 specimens, of which only seven have been located at BM, that were loaned to Lindley in 1837 mostly without collector details.

The date of Mangles' departure from Swan River is not known with certainty but he may have left on the *Egyptian* on 28 December 1831, apparently the only passenger ship to call at Fremantle after June (http://www.perthdps.com/shipping/). However, a passenger list has not been seen and G.F. Moore (1884: 64) was able to send correspondence out earlier, in September, via *The Cruizer*. References to Mangles presence at Swan River disappeared from Moore's diary in late July, 1831. Regardless, Mangles was certainly there longer than three months, probably four, and possibly as long as eight months. While there, he made the acquaintance of the gregarious Dublin-born member of the ruling elite, George Fletcher Moore, wealthy lawyer, singer, and ultimately extensive landowner, Advocate-General and also, for a time later, Acting Colonial Secretary.

Moore's published diary and correspondence (Doyle 1834, Moore 1884, Cameron 2006) is an important historical record of early settler life. Curiously, for a person interested in plants, Mangles seems to have formed no friendship with James Drummond (1786–1865), a working-class man, but the Colony's honorary botanist and naturalist, its most knowledgeable horticulturist, and ultimately its most important botanical collector. Apparently he preferred the company of his wealthy upper-class peers and relations. Possibly Mangles felt humiliated by Drummond who, when taken to see 'a frog with a tail' that Mangles had gleefully discovered, responded 'Hoot mon, it's naething but a tadpole' 'to the great mortification of Capt. M.' (Cameron 2006: 159–160). Although Cameron has published the most comprehensive version of Moore's diary and letters, he was apparently unaware of unpublished correspondence in Mangles' Letter Books.

After his return to England, according to Erickson (1969: 17), Mangles became 'infected with the fashionable fever for growing exotic plants', especially those from Western Australia, and then probably under the influence of his older brother, Robert. Robert Mangles (1781–1861), an independently wealthy landowner whose large home 'Whitmore Lodge' and garden at Sunning Hill, Berkshire, were described in fastidious detail by Loudon (1829), specialised in showing plants at exhibitions of the Horticultural Society of London. He was a leading exhibitor of newly introduced Swan River plants, for which he won numerous medals. As a cousin to Ellen Mangles, wife of the first Governor of the Swan River colony Sir James Stirling, he was especially favoured with seeds collected for his garden by them. There is no evidence that James Mangles returned with seeds to complement his specimens, among which there are, in any case, no specimens of *Grevillea manglesii*.

Although James Mangles had the advantage of incumbent wealth, Joseph Harrison (1839: 66) gave an insight to his centrality to plant introductions and a glowing impression of his generosity, writing 'We understand that [certain] flowering plants had been introduced into this country by Robert Mangles, Sunning Hill, Berks. but our correspondent informs us that the merit of introducing them, as well as a considerable number of the most showy of recent introduced plants, belongs to Captain Mangles R.N. That gentleman has been assiduously engaged for the last eight years, in introducing seeds from that most interesting portion of the globe, the Swan River colony. To accomplish so desirable an object, Captain Mangles went expressly on purpose, to see the flora of that country, and resided there for some time. To contribute to the pleasures of those interested in beautiful flowering plants in this country, Captain Mangles has expended a very considerable sum of money; and equally so in procuring and sending out presents of plants, books, maps &c from this country, to botanists resident at the Swan River colony, Ceylon, South Australia, Valparaiso, and other places with a view to stimulate them to collect and send seeds &c to this country. Immediately on receiving packets of seeds, with a liberality which entitles Captain Mangles to the thanks of every botanist in this country, they are distributed gratuitously to the principal nurserymen, and other plant establishments belonging to the Nobility and Gentry. We wish those persons having connexions [sic] in the distant and portions of the globe would imitate the very laudable zeal of Captain Mangles, introducing seeds of plants, and which in many instances might be procured at but a small expence [sic], we should soon have plants in our collections of many splendid flowers, of which we have only had descriptions, or a specimen sent us.'

Origins of Grevillea manglesii *Hort.*

The horticultural pedigree of *G. manglesii* Hort. is here examined, not least to correct the historical record, more broadly but also to perhaps identify the original seed collector and supplier. Donn (1845: 64), Sweet and D. Don (1839: 588) and Hereman (1868: 31) all agree on the year 1836 as the date of introduction for *Anadenia manglesii* in England, although Donn also treated *Grevillea manglesii* Hort as a synonym of *Manglesia glabrata*, and erroneously gave them a later date (1838). More importantly, no known listing in any European horticultural reference or catalogue predates the introduction of *G. manglesii* or its synonyms in England. Hooker (1841), following Graham (1839), stated that it was 'introduced to our gardens by Mr. Lowe [sic]'. However, Lindley (1840c) stated that '*Manglesia glabrata,* a synonym of *G. manglesii,* has found its way into gardens, having been raised from Swan River seed by Robert Mangles, Esq.' Consequently, unnamed grevilleas grown successfully from seed in or before 1836 by Robert Mangles and/or Hugh Low are particularly apposite to any investigation about the introduction of *Grevillea manglesii* Hort. and *Anadenia manglesii* Graham.

Although there are a number of candidate seed suppliers, among them Captain James Mangles himself, Governor Sir James Stirling or his wife Lady Ellen Stirling, William Morrison (fl. 1824–d. 1846), James Drummond or Johnston Drummond (1820–1845), his son, the last-named is revealed as the most likely contender, though none can be established or eliminated with complete certainty.

Sir James Stirling

In discussing the introduction of *Morna nitida* Lindl. (= *Waitzia nitida* (Lindl.) Paul G.Wilson), Lindley (1837a) reported that Robert Mangles had received seeds direct from Governor Sir James Stirling in January 1835, some of which germinated in 1836. Subsequently he (*ibid.*: 1837b) published a correction by Donald Mackay, Robert

Mangles' gardener, who stated that the 'seeds were imported..in the beginning of 1836 by Mr Robert Mangles, sown the 2nd February 1836 in rich light mould…'. No mention was made of Stirling as the source in this revised but still relevant account. Several authors have independently named Stirling as the source of seeds for other cultivated Swan-river species and James Mangles (c.1838) confirmed them, stating there that Stirling was also responsible for seeds of *Rhodanthe manglesii* Lindl., about which it might easily be assumed from Lindley (1834) that the source was James Mangles himself. Apart from seeds remitted from the colony, Don (1835a) reported that Stirling brought seeds back to England in 1832 and gave them personally to Robert Mangles.

Additional Australian species sourced to Stirling that flowered and were illustrated or otherwise treated or mentioned in English journals were *Anigozanthos rufus* Labill. (Loudon 1834), *Anigozanthos manglesii* D.Don (Don 1835a), *Rhodanthe manglesii* (Don 1835b), *Kennedya marryattae* Benth. [= *Kennedia lateritia* F.Muell.] (Lindley 1835), *Kennedya stirlingii* Lindl. (an *orth. var.* of *Kennedia stirlingii*) (Lindley 1836a), *Kennedya ?macrophylla* Lindl. (= *Hardenbergia comptoniana* (Andrews) Benth.) (Lindley 1836b). Although Lindley (1837c) claimed Stirling as the source of *Hibiscus lilacinus* Lindl. (= *Alyogyne* sp. Geraldton (R.Davis 3487)), Mangles credits 'Lady Stirling'. Lindley (1837d) also claimed that Stirling was the supplier of *Anigozanthos manglesii* var. *angustifolia* Lindl. but Mangles (1838c) claimed, on his list, that 'Moore' was the source of this species, as well as *Morna nitida*. Of course, Moore did not collect any seed on his own account at this time, but if we assume that Mangles meant Drummond via Moore, additional evidence will be here adduced in support.

William Morrison

If Stirling is to be accepted as the source of early horticultural seed supply, it is reasonable to imagine that he had an assistant. William Morrison (fl. 1824–d. 1846), who gained a reputation as a seed collector in Western Australia, was strongly connected to Stirling, but, apart from occasional notes (e.g. Maiden 1909), Erickson (1969), Cameron (2006), a few contemporary newspaper articles, and a short biography in George (2009), little is known about him. Morrison was born in Renfrew, Scotland, but was recruited personally from Kew Gardens by Sir James Stirling in 1833. Morrison was working there as a gardener under John Smith (1798–1888), who was appointed the first curator when it became a public botanic garden in 1841. When Stirling returned to Western Australia in 1834, having earlier (in August 1832) travelled back to England to raise funds and seek new emigrants, he appointed Morrison to superintend 27 boys, aged 8–18 years old, 'a disorderly set' that Stirling had rounded up in various London parishes (Morrison 1833). Delayed for several months at Portsmouth and Spithead by weather unsuitable for sailing, Morrison twice wrote to Smith begging for a loan, informing him that he had run out of money. As a postscript, he reported that 17 of the boys had deserted (Morrison 1834). Morrison was already an alcoholic, reportedly addicted to rum from before 1828 when he was a sugar plantation manager in the West Indies. His source of income is uncertain. He may have received money from Kew to collect plants but may also have worked for the Stirlings as part-time gardener after his arrival in Western Australia.

During this time, he also undertook journeys of exploration around Perth. 'He is certainly very indefatigable in collecting and goes to out of the way places in the course of his searches' wrote Moore (1839). From 1837 he began to engage with James Mangles' correspondents, George F. Moore, and Captain Richard Meares (1780–1862), supplying them with seed and identifying plants and specimens. John Smith (1880) recorded not only that Morrison 'sent many seeds to this country and many of the first of Proteaceae' but, more significantly, that he was 'the first in the field, before Drummond'. Lack of any record or other evidence suggests that it is unlikely that Morrison ever gathered seed of *G. manglesii* or included it in collections of seeds sent to London for sale before 1836 on his own account. According to Moore (1837), who sent a small parcel of seed collected by Morrison to Mangles, Morrison was by then 'addicted to intemperance by which he nearly lost his life on a recent occasion' (See Perth Gazette 5 August 1837, P. 948 for further detail). The assumed connection between Morrison and Stirling is certainly speculative but it accounts for Morrison's movements and activities immediately after his arrival in 1834, as well as the supply of seed flowing from Stirling. Collecting seeds for his wife's cousin could be seen as a somewhat implausible occupation for the busy Governor himself.

James Drummond

The initiation of a trade in plants/seeds between England and the Swan River colony began in earnest with a request for seeds in a letter (written and sent in triplicate) on 24 November 1834 by Captain James Mangles to George Fletcher Moore. Two copies of the letter arrived together at Fremantle via the *Sir David Ogilby* on or about 5 July 1835 (Moore 1884: 271). The letter contained an order for £5 (=AUD$800–900 in 2020 money) worth of seeds. In order that he might fulfil Mangles' request, perhaps by the same ship returning, Moore went immediately to see James Drummond who had been recently retrenched from his paid employment as Superintendent of the Government Garden and had removed himself and family to his grant in the Helena Valley (Erickson 1969). Drummond was deciding on a new career, whether as farmer, or seed and plant collector (Drummond 1836). Moore purchased 100 packages of seeds containing 'a complete assortment

of all the varieties of this colony' to fill Mangles' order. The seeds had been collected by one of Drummond's sons 'under the immediate superintendence of his father' for sale and export at 1/- per pack (Moore 1835a). Johnston, son of James Drummond, was, from the age of 15 (in 1835) collecting seeds, bird skins etc for sale in Cape Town (Drummond 1836) and it was to there that the collected seeds were probably intended before Moore laid claim to them.

Moore's first consignment of seeds arrived at James Mangles' address (York Chambers, London) on 29 January 1836, according to a note (?written by Mangles) on the accompanying itemised list (Moore 1835a). The seeds, which included five packets of unnamed *Grevillea* and five of 'Proteacea', had been collected mainly at Swan River, with some seeds [not provenance-listed] from Vasse, Augusta, King George's Sound. Despite the acknowledgement of Drummond's son Johnston as collector in Moore's letter, the list he sent to Mangles records that all seeds had been collected and named by 'Mr Drummond, the Botanist' (J. Mangles, undated b). Mangles adopted his customary practice of distributing the seeds, always some to his older brother Robert, as well as to his aristocratic friends and favoured nurserymen. Although in later years Low's nursery was not a regular recipient of Mangles' disposals, no doubt because he was importing seeds directly from Drummond himself, he may have received seeds from this consignment, either directly or through Robert Mangles, in the same way that Sir Joseph Paxton (1803–61), gardener to William Cavendish, Duke of Devonshire, received seeds from Mangles directed to him through Low (Paxton 1838). Low's Clapton Nursery also seems to have been the likely common source of sale and distribution of *Grevillea manglesii* within the United Kingdom, certainly to Scotland, and probably the rest of Europe, where plants in cultivation are recorded with the same name in Austria, Germany, France and Italy, from as early as 1837 (Rinz (1838–39), Baumann et fils (1841), Endlicher (1842), Seidel (1846) Pépin (1838), Planchon (1858).

Although seeds sent by George Fletcher Moore in 1835 to James Mangles were the probable source for the introduction of *Grevillea manglesii* Hort. and *Anadenia manglesii*, nowhere is it directly stated and, without further evidence, cannot be proved. Although preserved correspondence (Drummond 1837) between Drummond and Loddiges' Nursery indicates that Swan River seeds and plants were despatched to them at some stage, *G. manglesii* did not subsequently appear in their sale catalogue (e.g. Loddiges 1849). Drummond had also earlier sent a few seeds himself in a letter dated September 1835 in his correspondence with Mangles. 'The few seeds I enclose you in this letter' he wrote 'are all of particular beautiful plants, they are all good, but the beautiful scarlet *Grevillea* [probably *G. wilsonii* A.Cunn.] which I fear is scarcely ripe enough, is a most magnificent plant growing about 6 feet in height in large spreading bushes in the sort of soil marked No. 2, so it will be of importance to have that examined for the sake of being able to grow among the fine plants of this colony to perfection'. There is no further account of this despatch in the historical evidence, and certainly *G. manglesii* could have been among the seeds as it grows in locations and habitats similar to *G. wilsonii* in the Darling Range. However, the species is not particularly beautiful and seeds of *G. manglesii* included by Drummond on this occasion are considered here to have been an unlikely inclusion.

Erickson (1969: 21) documents however that the seeds sent by Moore 'proved valueless, for grubs destroyed the contents of all the packets', the evidence no doubt being a letter from Drummond to Mangles (Drummond 1836) in which he wrote 'I was sorry to hear that the seeds sent you by Mr Moore were destroyed by grubs. I will take particular care in future that the eggs of insects are not put up along with them.' This statement of events is in serious conflict with historical evidence presented here. Drummond was misinformed, it seems, and the seeds in question were probably those he sent in September 1835.

In April 1836, Robert Mangles (1836a), a weekly correspondent with his brother around this time, wrote with reports of successful germination of a large number of Swan River seeds. A more detailed report was given by letter in October (*ibid.*: 1836b) in which five different but unnamed species or varieties of *Grevillea* were germinated, along with many other species, roughly consistent with Moore's list. One of the unnamed *Grevillea* species was almost certainly *Grevillea manglesii* Hort. The fate of the remaining four species germinated by Robert Mangles is unclear. However, Donn (1845) listed, as *nomina nuda*, four species in *Anadenia* that were also introduced in 1836 with *Anadenia manglesii*, species otherwise unaccounted from any other known source but all described by Lindley in 1839 viz. *A. aquifolia* Lindl. (= *G. monticola* Meisn.), *A. flexuosa* Lindl. (= *G. flexuosa* (Lindl.) Meisn., *A. gracilis* Lindl. (= *G. synapheae* R.Br.) and *A. tenuiflora* Lindl. (= *G. tenuiflora* (R.Br.) Meisn.). It is possible that, when specimens of these species were collected by Drummond at various times, seeds were also collected when available and were therefore included among those purchased by G.F. Moore.

Ellen Stirling

Robert Mangles (1836a) also indicated that he had received seeds from his cousin Ellen Stirling in April 1836, from which he had successfully germinated *Chorizema cordatum* Lindl., the cultivated specimen formally described in 1838 by Lindley (1838f). While Ellen Stirling wrote and certainly sent seed to James Mangles,

there is no further reference to this despatch and it is thought that these were the only seeds sent or successfully germinated on that occasion.

Hugh Low

Heynhold (1840: 368) listed *Grevillea manglesii* Mack., without synonyms, confirming that the name was used (and probably arose) at Mackay's Clapton nursery, famed for its introductions of Australian plants, which had been taken over in 1831 and eventually renamed Low's Clapton Nursery by Hugh Low (1793–1863). Lindley (1831: t. 1423) stated that Low had been 'eight years foreman' in the establishment and one 'to whose careful management the success that has attended the raising the many important collections received by Messrs Mackay and Co. during that period, is very much to be attributed.' These include seeds collected in the 1820s by William Baxter (1787–?1836). There appear to be no extant pre-1840 catalogues of Mackay's Clapton Nursery. However, lists appeared in several editions of the *Gardeners' Chronicle* (1841) under Hugh Low's name, where *Grevillea manglesii* Hort. was offered for sale, *nomen nudum*, as *Manglesia glabrata*. It is likely that Heynhold derived his nomenclatural reference from access to an earlier sale catalogue of Low's that listed it as *Grevillea manglesii*, and which also probably circulated in Europe from 1837, judging from the cultivation of *G. manglesii* Hort. near Ris, France in 1838, under the same name (Pépin 1838).

It has been recorded (R. Barker 2005) that Low was a subscriber to James Drummond's collecting sets, because some specimens subsequently found their way to Kew, where they were presented in 1915 by the Linnean Society 'ex Hb. Hugh Low Esq.' (e.g. *Grevillea candolleana* Meisn. K799382, *G. drummondii* Meisn. K799511, *G. hookeriana* Meisn. K799240, *G. wilsonii* A.Cunn. K799525). Low probably could have afforded the cost, but was not a botanist who might have been interested in the majority of the species and there is no evidence that he received hundreds of specimens, 500 of which constituted a full set. However, an explanation for specimens in his possession might be contained in an undated note to Mangles (Drummond ?1838), in which Drummond wrote 'Mr Drummond would be much obliged by Captain Mangles showing the specimens of Proteaceae and others to Mr Low of the Clapton Nursery or a person he may send to look, as most of them are plants of which he is sending him the seeds.' From this Drummond confirms that he collected both specimens and seeds. It is possible that Mangles gave Low the relevant specimens or a duplicate thereof.

Summary

The inescapable conclusion that the seeds sent by Governor Stirling which arrived in 'early'1836, and the despatch by G.F. Moore which reached James Mangles on the 29th of January 1836' were one and the same, cannot be overstated. That Drummond misunderstood or was misinformed about the state of most of the seeds sent by Moore is also shown by the evidence. The seeds (or most of them) were distributed to Robert Mangles, who germinated a large number (R.Mangles 1836a, 1836b), and through him probably also to Hugh Low (the only evidence being that Low had saleable plants of *G. manglesii* in 1837). Mangles letter (1836b) dispels any doubt that the seeds he lists are anything other than the seeds sent by Moore.

Pierre-Denis Pépin

According to Carrière (1876), Pierre-Denis Pépin (1802–1876) was the head gardener (chef de l'École de Botanique) at the 'Jardin' of the Natural History Museum, Paris where he worked for more than 60 years, in the process being awarded a Legion of Honour. Pépin and the nurseryman Henri Antoine Jacques (1782–1866), ultimately head gardener at Neuilly to King Louis Philippe 1, were contemporaries and both contributed articles to the French horticultural journals *Annales de flore et de pomone,* as well as *Bon Jardinier* and *Revue Horticole.*

Pépin's description (see below) of *Grevillea manglesii* which predates and supplants that of Graham, was submitted to Karen L. Wilson, a member of the General Committee on Nomenclature (ICN), who advised (27 January 2021) that 'In general, the view has been that there has to be at least one descriptive feature that, AT THE TIME OF PUBLICATION, would have uniquely singled out a particular taxon that was known to botanists in that era. So, for example, saying a plant had green leaves would not be adequate at any time for valid publication, but saying that it was a *Grevillea* with leaves looking often like those of *Ginkgo* back in 1838 MIGHT have been enough if there was, at that time, only one known species that had such leaves, i.e. it would be a unique feature. The existence or not of a specimen would be irrelevant to the valid publication of the name.'

Taxonomy

McGillivray (1986) recognised one autonymic and two non-autonymic subspecies in *G. glabrata* (Lindl.) Meisn., a name which was subsequently superseded nomenclaturally by *G. manglesii*. The subspecies recognised in the former correspond exactly with those in the latter species. The two non-autonymic subspecies recognised were subsp. *ornithopoda* (Meisn.) McGill. and subsp. *dissectifolia* McGill. Neither at the time of their initial

description nor in subsequent treatments has any argument been advanced for their recognition above the rank of subspecies, notwithstanding their occurrence in allopatric populations that are fully and reliably distinguishable and in which there is no evidence of morphological overlap or interbreeding.

McGillivray was philosophically adherent to his own very broad interpretation of the Biological Species Concept (BSC). Species were defined, following Ernst Meyer's definition, as 'a genetically distinct interbreeding group of organisms' and that 'the genetic distinctness of a species was evident from its phenotype' (McGillivray 1994: 3). However, since the capacity to interbreed had to be assumed for allopatric populations determined as subspecies, their relationship and classification was based on the conceptualised autonymic phenotype. In the McGillivray classification model, non-autonymic subspecies are fully distinguishable, and their inclusion as segregates of the autonymic phenotype required a judgement that these population-level differences were somehow trivial or taxonomically less important than characters used to justify recognition of distinct species. In particular, his focus on consistency in floral and inflorescence structure as pre-eminent and the treatment of other characters, both sexual and non-sexual, as less significant has resulted in differences of opinion, culminating already in the deconstruction of several of his species by advocates of a narrower species concept. Olde and Marriott (1993), who then held a similar biological species concept before subsequently and recently adopting a phylogenetic model, continued this trend, but even they recognised subspecies that now warrant reconsideration of their rank.

Results from techniques, not then available to McGillivray, but developed subsequently, to examine phylogeny and analyse relationships, have repeatedly shown that morphology is not necessarily a reliable guide to relationships. Holmes *et al.* (2014) resolved *Grevillea montis-cole* subsp. *brevistyla* R.V.Sm. in a different clade from subsp. *montis-cole* R.V.Sm. Other supposed close relationships between *Grevillea* species were similarly unmasked in the time-calibrated phylogeny of subtribe Hakeinae presented by Mast *et al.* (2015). Moreover, the Phylogenetic Species Concept in one form or another has largely replaced the Biological Species Concept in systematics.

Phylogenetic species are never broadly conceptualised or seen as reproductive isolates with a focus on sexual characters but rather as holistic organisms or population-level units of an ancestor-descendent lineage. The operational definition of a phylogenetic species, here endorsed, has been given by Grubb and Groves (2011: 1) who treated them as 'the smallest population or aggregation of populations with heritable differences from other such populations or aggregations'. Small morphologically discontinuous differences at the population level can be seen as an evolutionary step and can be accepted *prima facie* as evidence of lineage separation, especially in allopatric species segregates. They can be diagnosed by a unique character or combination of character states that are not necessarily autapomorphic, in a system where all characters are equal, and not assembled into an hierarchy. Moreover, these populations can be tested and relationships inferred. They rebut the notion of reproductive isolation as a definition of species because molecular studies have shown that species do share genes in nature but can still persist as discrete entities. There is no further need to explain what isolating mechanisms are, nor how and why they might break down. Introgression or occasional hybrids in sympatric species in the wild are to be expected between closely related species and isolating mechanisms seem to rarely present a problem to horticultural breeders wishing to create hybrids.

In such a scheme, the rank of subspecies is questionable. Subspecies are usually defined as allopatric or geological population(s) that differ morphologically and perhaps genetically very slightly but not discontinuously from nomino-typical populations and are capable of interbreeding, though this latter proof is usually wanting *in situ*. Grubb and Groves (2011) indicate that 'good' subspecies are 100% diagnosable; 'hence they are actually distinct species masquerading as mere subspecies - victims of the general feeling around the mid-20th century (and certainly under the influence of the BSC) that taxa should be, if possible, relegated to the status of subspecies of the nearest species as long as they do not occur together.' There is an implied corollary also that some undefined species distance or degree of distinctiveness must be accepted. Although accepting subspecies as narrowly distinct species runs the risk of taxonomic inflation, according to criticism from those who argue that 'trivial' differences simply constitute phenotypic variation, there is no evidence that this is imminent. Trivial differences can only be identified in a hierarchical approach in which some morphological characters are considered more important than others, such as floral or sexual characters (underpinned by the view that species can only evolve by sexual means cf. environmental pressures). Discontinuous phenotypic variation or 'small' morphological differences at the population level are here seen as an evolutionary step and can be accepted *prima facie* as evidence of lineage separation and therefore warrant co-equal, specific recognition.

Subspecies can be accepted when there is morphological overlap and differences can be diagnosed at high frequencies but not absolutely differentiated at the population level. The rank could also prove useful as a temporary category where different populations have been identified but require further analysis. Fully diagnosable taxa at subspecies rank require empirical evidence of inclusion, not simply subjective opinion.

Morphology

Species in the *Grevillea manglesii* assemblage are distinguished on the basis of their foliar differences. Other characters here summarised are not repeated under individual species description. A comparison of seedling morphology awaits analysis.

Summary of characters: *Mature plants* glabrous in all parts except occasionally where indicated, seed-obligate, stenobasic, putatively self-compatible. *Branchlets* sometimes glaucous, slender, subterete in cross-section, a faint rib decurrent from leaf base above. *Leaves* petiolate, slightly discolorous; *new growth* red, pink or coppery at tips, soon light green to bluish-green, scattered hairs usually evident on very young growth; *leaf and lobe apices* acute, spinescent; *leaf spines* 1.25–3 mm long, non-pungent to occasionally pungent; *leaf margins* flat or very shortly recurved, with a slightly thickened, discolorous marginal vein; *basal internode* when present, not reduced in length when subtending axillary growth; *adaxial surface* dull, the midvein evident, secondary veins relatively obscure; *abaxial surface* exposed, midvein prominently raised, reticulum obscure; *petioles* normal, the point of attachment truncate. *Conflorescences* simple–3-branched, terminal, subterminal and axillary, partially enclosed within foliage; *buds* 2–3 mm long, 1 mm wide, ovoid, forming and developing sequentially from base of principal rachis, not overarched by bractiform leaves, not arrested in development, pedunculate; *unit conflorescences c*. 3 cm diam. regular, subglobose, loose; *peduncles* erect or decurved in bud; *common bracts* 1.2–2 mm long, 0.5–0.9 mm wide, ovate-cymbiform or narrowly so, soon caducous. *Flower colour*: *Pedicels and perianth* usually white, often pink, the limb lemon-yellow; pistils white the pollen-presenter often ageing pink. *Flowers* actinomorphic externally, zygomorphic internally, the carpel acroscopic, slightly fragrant, scarcely to not nectariferous, entomophilous. *Pedicels* 8–15 mm long; *torus c*. 0.5 mm across, transverse to slightly oblique; *nectary* rising c. 0.2 mm above the toral rim, arcuate to oblong with upper margin entire, sometimes shortly recurved; *pistil* 3.3–5.5 mm long; stylar swelling *c*.0.5 mm maximum width, ovoid, sometimes appearing subsessile; *pollen-presenter* conical, its base wider than the style-end; *stigma* 0.1–0.2 mm across; *perianth* actinomorphic, sometimes a few simple hairs on the adaxial surface; *limb* 1.3–1.7 mm wide, globose; *fruits* 7–10.5 mm long, follicular, one-seeded, oblong-obovoid; *exocarp* rugose, smoothly ridged or with rounded verrucae; *mesocarp* crustaceous.

Conflorescence development in the *Grevillea manglesii* assemblage follows a complex development pattern that is reflected throughout the *Triloba* Group. Branched conflorescences develop basipetally whereas individual unit conflorescences develop acropetally. The branch buds form sequentially and develop quickly from at or near the base, when most of the flowers in the distal unit(s) have reached anthesis or almost so. This pattern of flowering effectively extends flowering time rather than intensifies it, which would occur if all the branches and all the flowers in a unit conflorescence developed synchronously.

Interim key to distinguish species in the *Grevillea manglesii* assemblage adapted from Olde and Marriott (1994: 195)

14 Branchlets, leaves, peduncles and floral rachises glabrous

A Some or all leaves with secondary division, rarely simple; primary division frequent but not confined to the leaf apex; divided leaves 2–4.5(–5) cm long

B Leaves flat to irregular, trifid to bipinnatifid in the distal half; ultimate lobes of twice-divided leaves 0.3–1(–3) mm long, triangular, shallowly -fid; proximal lobes deeply dissected or not, but usually ascending ..... ***G. manglesii***

B* Leaves slightly divaricate, deeply dissected in the distal half; ultimate lobes of twice-divided leaves 7–20 mm long, linear to narrow-triangular; proximal lobes deeply dissected and spreading widely, sometimes descending ..... ***G. dissectifolia***

A* All leaves simple or with primary apical division only; divided leaves 5–8 cm long ..... ***G. ornithopoda***

14* Either branchlets, leaves, peduncles or floral rachises densely to sparsely hairy.

Nomenclature and taxonomy

Grevillea manglesii Pépin, *Annales de flore et de pomone* 1837–1838, p. 381 (1838), as 'Manglesii'.

Protologue. *Grevillea manglesii,* d'orangerie, et dont les feuilles, quoique très-variables, rassemblant le plus souvent a celles du *Ginkgo biloba*. [*Grevillea manglesii,* from the conservatory, the leaves of which, although very variable, resemble more often than not those of *Ginkgo biloba*.]

Neotype (here designated) [Paris, France] 'Grevillea Manglesii' P03354112 ex Hb. Jacques.

http://mediaphoto.mnhn.fr/media/1441335820687jkjFuTNWFJBYK4Ay (Fig. 1)

Fig. 1. Designated neotype of *Grevillea manglesii* Pépin (P03354112).

Discussion: Pépin wrote a report, published in *Annales de flore et de pomone* for 1838, on the plants in the 'orangerie' of the 'bel établissement de Fromont', which contained three *Grevillea* species. At that time (*fide* De Gaulle 1841), the Château de Fromont was unrivalled in Europe for its collection of exotic and rare plants from all over the world under the directorship of M. Soulange-Bodin. However, there is no appropriately dated *Grevillea* specimen collected from this garden at P. An undated specimen collected by Henri Antoine Jacques (1782–1866) of a plant in cultivation at the 'Museum National d'Histoire Naturelle' of which Pépin was the head gardener, is therefore proposed as neotype. This specimen is considered the most authentic, in the absence of a specimen collected by Pépin himself, above other anonymously collected candidate specimens at P, (P3354110, P3354111) collected at 'Hort. Bot. Parisiensis', all of which postdate Pépin's article. Jacques was a journalistic colleague of Pépin, and a well-known and informed horticulturist, nurseryman.

The reference and association with leaves of *Ginkgo biloba* (see Fig. 2) identifies the species in sufficiently clear terms to accept the name *Grevillea manglesii* as validly published by Pépin. The description predates the more extensive description by Graham, but is here regarded as both adequate and taxonomically sufficient because it enables recognition by reference to a unique character 'leaves very variable, but more often than not like *Ginkgo biloba*'. It is distinguished from all other species of *Grevillea* described prior to 1838, including those of Brown (1810) and (1830), and therefore, under the rules of botanical nomenclature (viz. Turland *et al.* 2018, Article 38.2 and 38.4 ex.9), is here taken as valid publication of the name.

Fig. 2. Flowers and foliage of *Grevillea manglesii*. Photo: P. Olde. Inset: Follicle. Photo: M. Noake.

Should acceptance of Pépin's description be successfully challenged as inadequate, the name of the species will not change but will revert to a process of linkage to *Anadenia manglesii* Graham. However, a change to the current authority would be needed to take account of an earlier combination. The revised authority would be *Grevillea manglesii* (Graham) A.Baumann and N.Baumann. Correspondence between Eugène Baumann on behalf of the Baumann brothers' nursery is contained in Mangles Letter Books which explains their early access to plant introductions.

The link to Pépin's description was provided to the author in a communication dated 21 January 2021, by Professor David Mabberley. According to IPNI, Pépin is the author of eight published names, seven of which were published in the *Annales de flore et de Pomone*.

Anadenia manglesii Graham, *Edinburgh New Philosophical Journal* 27 (53): 189 (1839), as 'Manglesii'. Graham in Hook., *Icones Plantarum* 4: t. 337! (1841), *isonym*.

Grevillea manglesii (Graham) A.Baumann and N.Baumann, *Catalogue des végétaux en tous genres* 27 (1843); (Graham) T.J.Seidel, *Neue allgemeine deutsche Garten und Blumenzeitung* 2: 103 (1846), *isonym*; Planchon, *Hortus Donatensis* 96 (1858), *isonym*; McGillivray and Makinson, *Grevillea* 427 (1993), *isonym*. *Hakea manglesii* (Graham) Christenh. and Byng, *Global Flora* 4: 85 (2018), *nomen illeg.*

Type citation: [United Kingdom, Edinburgh, Scotland, cultivated]. 'We received this plant at the Botanic Garden, Edinburgh, from Mr Lowe [sic] of the Clapton nursery, in 1837, under the name of Grevillea Manglesii. The flowers are small but being very numerous, covering the whole plant, and remaining long in perfection, it is far from being destitute of beauty. It first came into flower in the greenhouse, under the ordinary treatment of New Holland plants, in March, and now (31st May), though the spikes of expanded flowers are clustered at the apex of every branch, there is a long succession of undeveloped buds.'

Neotype: (designated by McGillivray and Makinson 1993: 427) 'Anadenia manglesii 25 July 1839, this name I have somewhere published it, but it was sent to me under the name of Grevillea Manglesii. It certainly is no Grevillea.' [R.Graham script] E00438973.

Note: McGillivray and Makinson (1993: 427) found that Graham did not preserve, annotate or date any specimens associated with his 'June' description. In proposing a neotype dated July, they discussed two other possibilities; two Drummond specimens at E annotated '*Anadenia manglesii*', which they noted were only indirectly implicated, and 'the plate' (discussed earlier). The Drummond specimens indeed are too indirect and uncertain a link, even though they could represent 'voucher' sources of the seeds germinated by Low or Robert Mangles. Their proposal to designate a cultivated specimen annotated by Graham as neotype is supported here.

SYNONYMS

Manglesia cuneata Endl. in Endlicher and Fenzl, *Novarum Stirpium Decades* 25 (1839), *nomen nudum*; Endl. ex Steud., *Nomenclator* ed 2, 2: 98 (1841), *nom. illeg. superfl. pro A. manglesii*. *Grevillea cuneata* (Endl.) Druce, *Bot. Soc. Exch. Club Brit. Isles* 4(5) Suppl. 2: 625 (1917), *nomen illeg.*

Grevillea manglesii Hort. ex Endl., *Novarum Stirpium Decades* 25 (1839), *nomen in syn.*; Steud., *Nomenclator Botanicus* ed. 2, 2: 705 (1841), *nomen nudum;* Heynhold, *Nomenclator botanicus hortensis* Vol. 2: 385 (1846), *nomen nudum*.

Grevillea manglesii J.B.Mackay ex Heynh., *Nomenclator* 368 (1840), as 'Manglesii', *nomen nudum*.

Manglesia glabrata Lindl., *Sketch Veg. Swan R.*: xxxvii (1840). *Grevillea glabrata* (Lindl.) Meisn., in Lehmann, *Pl. Preiss.* 1: 549 (1845), *nom. illeg.* (*A. manglesii* in syn.).

Type: Not indicated.

Lectotype (designated here): [Western Australia] Swan River, *Drummond*, 1839 (CGE ex Hb. Lindley), specimen at left of sheet (see Fig. 3).

McGillivray and Makinson (1993: 427) have treated the lectotype as the holotype. There are a number of apparent duplicates of this collection, so even if the duplicates were not seen, the CGE specimen will not qualify as a holotype. The specimen at right mounted with the lectotype: Swan River, *Mr. Toward*, probably represents a 'voucher' source of the seeds germinated by Hugh Low or Robert Mangles i.e. *Grevillea manglesii* Hort ex Pépin. Toward never visited Australia but maintained an herbarium of the specimens under cultivation where he worked (see Loudon (1828b: 433) for an extended discussion).

McGillivray and Makinson (1993) also cited 'Neg. No. Kew 10531', suggesting that a photo of the lectotype is held at K. However, a search by Kew staff was unable to find it. Apparently this and similar Neg. numbers refer to sheets that were photographed at Kew, usually by request (in pre-scanning days). An alternate possibility is that this sheet is still actually held at K. A search of all specimens referable to *Grevillea* by Christine Bartram at CGE could not locate the lectotype, nor even a photo. However, there is a scanned photograph at the National Herbarium of NSW (not seen) and another in the Australian National Herbarium, Canberra, reproduced here.

Fig. 3. Image (held at CANB) of lectotype of *Manglesia glabrata* Lindl.

Isolectotypes: 'Communic. Lindley 1839' [hand of Meisner] BR0000013460273; 'Anadenia manglesii Graham in Hort. ic. t.337 [hand of R.Graham] 'Swan River, Drummond' [hand of ?Lindley] E00438974; 'Manglesia glabrata, Swan River, Drummond No. 66' [hand of ?Lindley] E00438975; 'Swan River, Drummond' (G-DC) G327722; '66 Swan River, Drummond'[hand of Lindley] K1096609; Swan River, Drummond'[hand of Lindley] K1096610; ?LE (*n.v.*); PERTH01000349 (photo).

Excluded specimens: 'Drummond 1st Coll No. 621' ?BM (not found); '621 Swan River Drummond [hand of Bentham] CGE12965 ex Hb. Lemann, specimen at right; '621' [Drummond label] G389366; 'Drummond 1. 621' MEL64486; 'Coll. 1 No 621 1843' P02370471 ex BM, 13 April 1923, as *Hakea glabrata*.

The excluded specimens are from Drummond's first collection *sensu* Hooker and were cited by McGillivray and Makinson (1993: 427) as 'POSSIBLE PARTS OF THE TYPE COLLECTION' of *Manglesia glabrata* Lindl. Numbered specimens from Drummond's First Collection *sensu* Hooker, collected May 1842, were not distributed until 1843, well after the date of Lindley's publication, *A Sketch of the vegetation of the Swan River Colony* (1839–1840), Before this time, most of Drummond's specimens are un-numbered, although Erickson (1969: 168) asserts that numbered specimens were first sent by Drummond in November 1839 via the *Shepherd*, arriving in England presumably some time in December that year. Maslin and George (2005: 37) also point out that Drummond did number early specimens, at least from 1839. The number 66 associated with some specimens of *Manglesia glabrata* could represent such a number, even though it was sent in late 1838. However, these numbers are not the same as those traditionally accepted under Hooker's numbering system which dates from 1842, when specimens were designated by Hooker as Coll. 1: and given a separate number in series. Most of the Drummond specimens utilised by Lindley appear to have arrived in April 1839 or earlier. A duplicate specimen of *Manglesia glabrata* was received at BM in July 1839.

? = *Manglesia trilobata* Hort. ex Ettingsh., *Denkschriften der Kaiserlichen Akademie der Wissenschaften, Mathematische-naturwissenschaftliche Klasse* 15: 181–272. 254, tab. 36, figs. 1–5 (1858).

Lectotype (here designated): [Illustration] Hort. ex Ettingsh., *loc. cit*., Tab. 36, figs 1–5.

https://www.biodiversitylibrary.org/page/6342869#page/371/mode/1up (Fig. 4).

Herbarium specimens have not been found. Plants were cultivated at Schönbrunn Palace, Vienna (see Olde 2017: 310).

Bushy, sometimes virgate *shrubs* 1.5–2.5(–3) m high, 1.5–2.5 m wide with spreading to ascending branches, some from close to base. *Branchlets* cream to green, often glaucous. *Leaves* simple and divided; simple leaves (P2370475) *c*. 2 cm long, *c*. 5 mm maximum width, narrowly obovate, occasional to rare; divided leaves (1–)2.2–4(–5) cm long, (0.8–)2.5–4(–5) cm maximum width, with variable orders of division even on the same leaf, but always some leaves with secondary division, sometimes either obovate-cuneate with apical 3–5-lobing, or, most usually, trifid to pinnatifid with 3 (–7) deeply or shallowly divided primary lobes, the primary lobes often or all secondarily 2–3-fid, the basal primary lobes sometimes deeply dissected, dentate or bifid to trifid; *leaf rachis* straight or gently recurved; *ultimate leaf lobes of secondarily divided leaves* 0.3–3(–5) mm long, 3–8 mm wide, triangular, ascending to spreading; *central primary lobes* bi- or tri-fid with shallow incisions; *basal internode* rarely absent, 2–10 mm long, linear or very narrow-cuneate; *leaf base* truncate to broadly cuneate or cuneate; *adaxial surface* irregularly undulate; *texture* papyraceous to coriaceous.

Distribution: Western Australia. Grows in the Northern Jarrah Forest IBRA Subregion of the Jarrah Forest IBRA Region, in the Beverley and Perth Local Government Areas.

Phenology: Flowers from mid-winter (July) through spring to early summer.

Habitat and ecology: Grows mainly in wandoo or jarrah/marri forest and often with *Corymbia calophylla* (marri) in well-drained situations above drainage lines or watercourses, often in association with outcropping granite. Soils preferred are clay-loam or grey sand with laterite. Grows mainly in Proteaceae scrub in association with *Grevillea bipinnatifida, G. endlicheriana, G. hislopii, G. pilulifera, Hypocalymma angustifolium, Leptospermum erubescens, Synaphea acutiloba* and *Xanthorrhoea preissii*.

Conservation status: According to the Western Australian Herbarium, this species is Not Threatened.

Etymology: McGillivray and Makinson (1993: 427) have stated that the epithet is probably associated with Captain James Mangles, the man at the centre of seed distribution between 1834–1845, but in view of its horticultural history, it may actually be his older brother Robert Mangles (1781–1861) for whom it was named, probably by Low. However, firm evidence that Low coined the epithet is lacking and the author citation cannot include him.

Fig. 4. Lectotype of *Manglesia trilobata* Ettingsh. (Figs 1–5).

Specimens seen: Western Australia. Hort. bot. Vindobonensis, *Anon. s.n.*, *s.d.*, (P750707 ex Hb Drake); Hort bot. Parisiensis, *Anon. s.n.*, May 1842 (P3354111); 4.5 km SW Carinyah, *R. Davis 4095*, 18 July 1997 (PERTH4811402); 2.3 km S of McCallum Rd on track c. 3km E of Watershed Rd. Gibbs State Forest Block, *G. Keighery 6797, N. Gibson,* 27 Sep 2000 (PERTH6823785); Wooroloo, *M. Koch 1518*, Nov 1906 (P2370475, PERTH01803581); Mundaring Weir, Darling Range, *P.M. Olde* 86/277, 6 Sep 1986 (NSW977404); Mt Observation, 59 km E of Perth towards York, *P.M. Olde* 86/840, 9 Oct 1986 (NSW977402); along exit road from Serpentine Dam car-park, Jarrahdale, *P.M. Olde* 86/983, 28 Oct 1986 (NSW977032); Brookton Highway, 10.9 km SE of Ashendon Rd., Canning Reservoir, *P.M. Olde* 91/245, 5 Oct 1991 (NSW362886); Measuring station via spur track off Reservoir Rd towards dam. *P.M. Olde 02/77, N. Marriott*, 5 Sep 2002 (NSW535252); Talbot Road Reserve, Talbot Rd., Swan View, *P.M. Olde* 13/223, 7 Sept 2013 (NSW); prope villam Harris ad fluvium Cygnorum, *L. Preiss* 895, July 1839 (P2370473 ex Hb Drake); Parkerville, Swan District, *E. Pritzel 49*, Nov 1900 (P2370477, PERTH01803603).

Grevillea dissectifolia (McGill.) Olde, **comb. et stat. nov**.

Basionym: *Grevillea glabrata* subsp. *dissectifolia* McGill., *New Names in Grevillea*: 6 (1986).

Type: [Western Australia] 11 km N of North Bannister on the Albany Highway, *D.J. McGillivray 3468,& A.S. George*, 23 Jun 1976 (holo: NSW621065 including packet; iso: K000799575 ex NSW; MEL2174176; NY (*?distribuendi*); PERTH01108700.

Bushy *shrubs* 2–2.5 m high 1.5–3 m wide with spreading branches. *Branchlets* usually red, at least sometimes non-glaucous. *Leaves* divided, 2–4.5 cm long, 2–6 cm wide, broadly ovate to obovate in gross outline, polymorphic, usually biternate, sometimes ternate with the lateral lobes secondarily bipartite, or rarely bipartite with the tripartite secondary division, or very rarely a few leaves simply tripartite or the central lobe with tertiary bifid division; *leaf rachis* smoothly recurved; *ultimate leaf lobes* 6–35 mm long, 2–4 mm wide, narrow-triangular or narrow-elliptic; *primary lobes* widely divergent to orthogonal; *central lobe* sub-divaricate; *basal internode* 13–22 mm long, linear to very narrow-cuneate; *adaxial surface of ultimate lobes* flat to angularly concave; *abaxial surfaces* narrowly exposed; *texture* papyraceous to coriaceous. (Figs 5–7).

Distribution: Western Australia, in the Northern Jarrah Forest IBRA Subregion of the Jarrah Forest IBRA Region in the Armadale, Beverley, Boddington, Mundaring, Murray, Wandering Local Government Areas according to Florabase (consulted 10 July 2021).

Phenology: Flowering commences May (in cult.) and continues densely or spasmodically at least until November. Fruits are usually present from October.

Habitat and ecology: Grows in Eucalypt forest (*Corymbia calophylla, Eucalyptus marginata, E. wandoo, E. patens*) or *Allocasuarina huegeliana* dominated woodland with *Xanthorrhoea preissii, Acacia pulchella*, *Grevillea* and *Hakea* spp. in moist situations or depressions in gravelly soils recorded as brown or yellow sand, loam or clay, sometimes in heavy laterite with exposed granite sheet or outcrops. Associated species in one location included *Eucalyptus decurva, Banksia armata, B. dallaneyi, Allocasuarina humilis, Grevillea cirsiifolia, G. bipinnatifida, Leucopogon sp., Pericalymma ellipticum, Stenanthemum nanum, S. pumilum, Jacksonia racemosa* and *Petrophile* sp. Additional species at a nearby site included *Hakea trifurcata, H. undulata, Banksia fraseri, Stirlingia simplex, Persoonia quinquenervis* and *Xanthorrhoea preissii.*

Conservation status: A conservation code of Priority Three has been designated by the Western Australian Herbarium. It occurs in several State Forests and Conservation Reserves, sometimes in large populations exceeding 1000.

Variation: Leaves vary from fine to coarse. The leaf division of *Hort* 2098 is very coarse and its inclusion in *G. dissectifolia* is provisional. Most populations have not been seen in the wild and adjustments to the circumscription may become necessary.

Discussion: *Grevillea dissectifolia* differs from *G. manglesii* in its leaves never simple and entire v. occasionally simple; its leaves all deeply and similarly dissected v. some deeply and others (mainly in the distal half of the leaf) coarsely and irregularly divided; its primary lateral leaf lobes widely divergent to patent, rarely descending v. ascending to rarely spreading; the base of the primary central lobe of ternately divided leaves 1–2 mm wide, linear to very narrow-cuneate v. 3–5 mm wide, cuneate to broadly cuneate; all leaves with 2–3 primary lobes, bipartite with tripartite secondary division, or biternate with narrow lobes 7–20 mm long, 1.3–2.8 mm wide v. some leaves with 5–7 primary lobes, pinnatid to bipinnatifid, the secondary lobes if present triangular 0.1–5 mm long, 2–8 mm wide; leaves never secondarily triangular-toothed v. some or all leaves secondarily triangular-toothed.

Fig. 5. *Grevillea dissectifolia*, Williams Rd, Boddington. A. Flowering branchlets. B. Follicles and leaves. Photos: F. & J. Hort.

Fig. 6. *Grevillea dissectifolia*. Flowering branch. Photo: I. Gilmour.

Fig. 7. *Grevillea dissectifolia*. Natural population, Boddington. Voucher: Hort 3948. Photo: J. Hort.

Although the proximal lateral lobes of *G. manglesii* are also sometimes deeply cleft almost to the midvein, the distal lobes are always coarsely divided with shallow angular incisions or embayments. Leaf orders of division range from simple to once- and twice-divided often on the same plant, and the ultimate, secondarily divided lobes are short (0.3–1(–5) mm long) subtriangular, flat, and often crowded together, the central lobe is straight, flat and the primary venation is more generally ascending than for *G. dissectifolia* from which it is well distinguished and fully diagnosable. The leaves of *G. dissectifolia* are usually similarly and deeply twice-dissected, bear a distinct basal internode (0.1–)1–2.2 cm long. The ultimate lobes are 6–20 mm long, linear to narrow-triangular and with an angularly concave adaxial surface, the central lobe sub-divaricate and all lobes similarly wide-spreading to patent.

Grevillea dissectifolia is clearly distinct from *G. ornithopoda* which is a tall shrub to small tree 3–4 m high, has simple, narrowly elliptic leaves or once-divided, apically lobed leaves 5–8 cm long with a cuneate base, and lacking a basal internode.

Selected specimens examined: Western Australia: 31 mile Rd [*c.*20 km SE of Armadale], Gleneagle, *R.J. Edmiston* H738, 1969 (PERTH1035711); Metro Rd, North Bannister (Worsley lease), *N. Eveleigh* 63, 6 July 2007 (PERTH08001553); Watershed Rd., 0.9 km S of Schulstaad Rd, Leona SF, Beverley, *F. Hort, B. Hort & R. Evans* 2131, 26 Nov 2003 (PERTH06692850); Helena Valley Rd., 900 m E of Ridge Hill Rd, *F. Hort* 255, 18 Oct 1998 (PERTH05299551); Metro Rd, Gibbs SF, Wandering, *F. Hort* 476 *& L. Robson*, 12 May 1999 (CANB527379, NSW498646, NSW520118, PERTH05311667); McCallum Rd, Gibbs SF, Beverley, *F. Hort* 477 *& L. Robson*, 13 May 1999 (CANB527380; PERTH05311675); Metro Rd, 4.5 km S of Division Track, then 800 m directly SE, *F & J. Hort* 501, 29 May 1999 (PERTH05369371); Monadnocks Conservation Park A39826, Millars Log Rd, 2.3 km E of Albany Hwy, Wandering, *F & B. Hort* 2098, 13 Nov 2003 (MEL, PERTH06692192); Serpentine River Crossing, Boonering SF, Williams Rd, Boddington, *F & J. Hort* FH3712, 11 Sept 2011 (CANB, PERTH08359776); Williams Rd, Boonering SF, Boddington, *F. Hort* FH3948 *& J. Hort*, 3 Sep 2015 (MEL2409455, PERTH8699968); Big Brook crossing, Forest Dept Reserve, Dwellingup, *P.C. Kimber* 227, 2 Sep 1966 (PERTH02118335); 11 km N of North Bannister on the Albany Highway, *D.J._McGillivray 3471 & A.S. George*, 23 June 1976 (NSW; PERTH01803395); Albany Highway, 28.9 km SW of Jarrahdale Rd, *P.M. Olde* 86/986, 28 Oct 1986 (NSW977134); S.E.C. N.T. 81 Powerline, Dwellingup District, *J.L. Robson* JLR650, 8 Nov 1996 (PERTH04865227); Youraling SF, *C. Tauss s.n.*, Aug 2004 (PERTH08011559).

Grevillea ornithopoda Meisn. *in* Lehm., *Pl. Preiss.* 2: 256 (1848).

Grevillea manglesii subsp. *ornithopoda* (Meisn.) McGill., in McGillivray and Makinson, *Grevillea:* 427 (1993).

Grevillea glabrata subsp. *ornithopoda* (Meisn.) McGill., *New Names in Grevillea*: 6 (1986).

Hakea ornithopoda (Meisn.) Christenh. and Byng, *Global Flora* 4: 87 (2018).

Type: [Western Australia] Swan River, Drummond. coll. II. No. 314.

Lectotype designated by McGillivray and Makinson (1993: 427): '*Drummond n. 314*! in hb. Shuttl.' [Meisner script] NY 00284671.

Isolectotypes: 'No. 314 Grevillea ornithopoda, Meissn W. Australia Drummond 2nd collection 1844' A00035409 ex BM; 'leg. J. Drummond' B_10_0279551 ex MEL, as *Diels* 7583; '314' [Drummond handwritten label] BM001121157; '314, Swan River, Drummond' CGE12984 ex Hb. Lemann; E00438972 ex BM; G389365; 'Swan R, J. Drummond 2nd ser No.314' K000579576 ex Hb. W. Saunders, presented by the Linnean Society 1915; K000599577 - whole sheet; 'S.W. Australia, Drummond 314' K000799579 -specimen at right of sheet; 'Swan River J. Drummond no. 314. /bis/' [J. G. Agardh's hand] LD1742676; 'Swan River J. Drummond no 314. bis' [J. G. Agardh's hand] LD1742356; '314' [Drummond label] 'II 314 Grevillea ornithopoda Meisn., Ad fl. Cygnorum leg. J. Drummond' LE00011506 ex Herb. Hort. Petropolitani; MEL65474; NY00284672; P00750730; P00750731 ex BM, reçu 13 April 1923; PERTH01057936 ex MEL.

Probable isolectotypes 'Drummond 6' K000599578 - Kew Neg No. 2347; *'J. Drummond 9 or 6'* MEL2174868. These specimens were possibly part of a set sent by Drummond to Hooker, prior to the major despatch.

Description: (Meisner 1848: 256) here translated: **Grevillea** (Manglesia) **ornithopoda** *C.F. Meisner* a completely glabrous plant, the leaves wedge-shaped, long attenuate-subpetiolate, flat, three-nerved, the apex trifid, the lobes subequal, narrowly lanceolate, entire, with a spiny mucro, the lateral lobes recurved-subfalcate; the racemes pedunculate, branched lower down; style filiform at base.]

Virgate *shrubs* or small *trees* (2–)3–5 m high, 1.5–2 m wide, with ascending branches. *Branchlets* cream. *Leaves* simple and divided; *simple leaves* 3–6 cm long, 2.5–4(–5) mm maximum width, narrow-obovate; *divided leaves* 5–8 cm long, 10–25 mm maximum width, obovate-cuneate, apically bi- or tri-partite with triangular lobes

from deep or shallow angular incisions; *leaf rachis* straight; *leaf lobes* 8–22(–33) mm long, 2–4 mm wide, subtriangular, ascending; *basal internode* absent, the distance from petiole attachment to the proximal vein sinus usually *c*. 30 mm; *adaxial surface of ultimate lobes* flat; texture papyraceous. (Fig. 8).

Fig. 8. *Grevillea ornithopoda* in cultivation, Oakdale, New South Wales. Photo: P. Olde.

Distribution: Western Australia. It occurs in the Northern Jarrah Forest and Swan Coastal plain IBRA Subregion of the Jarrah Forest IBRA Region, in the Mundaring, Murray, Perth, Serpentine-Jarrahdale, Waroona Local Government Areas.

Phenology: Flowers from late autumn through to late spring.

Habitat and ecology: Grows in open, often degraded *Eucalyptus rudis* forest in sandy gravelly loam beside watercourses and drainage lines of the Murray River. Recorded associated species include *Corymbia calophylla, Acacia pulchella, Jacksonia sternbergiana, Dodonaea viscosa, Melaleuca rhaphiophylla, Astartea affinis*.

Conservation status: A conservation code of Priority Two has been designated by the Western Australian Herbarium.

Etymology: The epithet is derived from the Greek, '*ornithos*' a bird, and '*podon*' a foot, in reference to the leaves, shaped like those of a bird's foot.

Discussion: *Grevillea ornithopoda* appears closely related to *G. manglesii* Pépin, but it is not here held to be the same species, most particularly in the absence of phylogenetic testing and scientific analysis. Now extremely rare in its natural habitat, its populations maintain, without intergrading with *G. manglesii*, a distinctive leaf morphology and a more tree-like habit. The leaves are obovate-cuneate, apically toothed and lack secondary division. Simple, narrow-elliptic leaves are also frequent. Differing orders of leaf division at the population level are held here to be significant in the recognition of species at that rank as originally proposed by Meisner (1848).

Selected specimens examined: Western Australia: Helena River, near Mundaring, *C.A. Gardner 549*, 11 June 1920 (PERTH01070150); Murray River, Pinjarra, *R. Helms s.n.*, 23 Sept 1897 (NSW125519, PERTH01070142); Little Yunderup Island, *G. Keighery 16138*, 15 Nov 2000 (PERTH06097375); Lane Poole Reserve, Dwellingup, *M.L. Mallie 104 & W. Birmingham*, 5 Apr 2017 (PERTH09197540); Jarrahdale, *A. Morrison* 765, Oct 1901 (PERTH01070576); Meelon Nature Reserve, SW of Pinjarra, *P.M. Olde 01/142 & N. Marriott*, 11 Sept 2001 (NSW535103).

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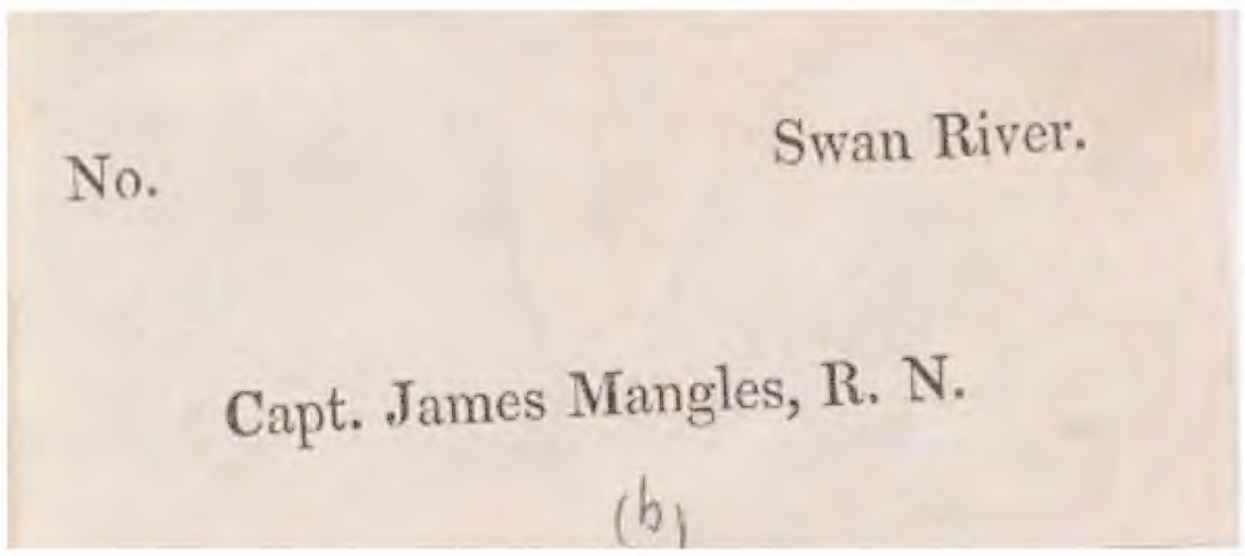

Fig. 9. Printed label for James Mangles specimens.

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Redescription of *Utricularia singeriana* and a new species *Utricularia baliboongarnang* Baleeiro & R.W.Jobson for north-eastern Western Australia

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We dedicate this work to the memory of our friend and colleague Mr Allen Lowrie whose work has advanced our understanding of the systematics and ecology of *Utricularia*.

Abstract

A new species of *Utricularia* (Lentibulariaceae) is recognised for north-eastern Western Australia. A description of *Utricularia baliboongarnang* Baleeiro & R.W.Jobson is provided along with a new circumscription for the Northern Territory species *U. singeriana* F.Muell. to which it was previously assigned. We also provide comparison with *U. hamiltonii* F.E.Lloyd, a Northern Territory species for which *U. baliboongarnang* was recently found to be the phylogenetic sister, and the distantly related western Kimberley species *U. byrneana* R.W.Jobson & Baleeiro with which it shares a superficially similar corolla. Diagnostic features are illustrated, a taxonomic key containing related species from northern Australia is provided, and distribution, habitat, and conservation status are discussed.

Introduction

Taylor (1989) placed *Utricularia singeriana* F.Muell. within section *Pleiochasia* Kamienski of subgen. *Polypompholyx* sensu Jobson *et al.* (2017) and included two disjunct collections from near Kununurra in Western Australia with those from the type region near Darwin in the Northern Territory. Cowie (2010) provides a morphological comparison of the *U. singeriana* collections from Kununurra with those from the Northern Territory. On close inspection Cowie (2010) realised that the two entities bear little resemblance to each other and proceeded to differentiate them based on the shape of leaves, corolla lower lip limb and spur, in addition to their geographic disjunction. The Darwin specimens that Taylor examined (*Holtze s.n.*) possessed a corolla that is smaller than is typical for the species, and this may have led to Taylor's inclusion of the specimens from Western Australia under his concept of *Utricularia singeriana*.

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The comparative study of Cowie (2010) led to the assignment of the informal phrase name *U.* sp. Kununurra (Glover 81) (https://florabase.dpaw.wa.gov.au/browse/profile/50363)in addition to the enhanced conservation status of both entities. This was later supported by both Lowrie (2013) and the recent molecular phylogenetic study of Jobson *et al.* (2017) who provided strong evidence that Taylor's concept of *U. singeriana* is indeed paraphyletic. In their study, Jobson *et al.* (2017) included accessions from the two known Kununurra sites finding that these were nested within a clade containing the Northern Territory endemic *U. hamiltonii* that were together sister to the Kimberly endemic *U. hamata* R.W.Jobson & M.D.Barrett. This latter species is only distantly related to the broadly sampled accessions fitting the type description and representing the concept of *U. singeriana* as it is outlined in Cowie (2010).

We here describe the taxon *U.* sp. Kununurra (Glover 81) as the new species *Utricularia baliboongarnang* Baleeiro & R.W.Jobson from the eastern Kimberly region of Western Australia. We also provide an updated taxonomic description for *U. singeriana* that is restricted to populations distributed across the Northern Territory (Fig. 5) and fitting the type material (Fig. 3). Morphological differences are compared between the newly described entity and its closely allied species *U. hamata* and *U. hamiltonii*, with notes on distribution, ecology and conservation status provided. An identification key representing the related species of section *Pleiochasia* from northern Australia also is provided.

Methods

Relevant dried and alcohol-preserved material representing all related species, held at the National Herbarium of New South Wales (NSW), Australian National Herbarium (CANB), Northern Territory Herbarium (DNA), Western Australia Herbarium (PERTH), and State Herbarium of South Australia (AD), were examined. Pollen characteristics were investigated using a standard compound microscope (magnification ×100).

Taxonomy

Utricularia singeriana F.Muell., *J. & Proc. Roy. Soc. New South Wales* 24: 76, 176 (1890).

Type: Port Darwin, N.T., *M.Holtze 1026*; holo: MEL (MEL 1513939); iso: K, MEL (MEL 1513940), NSW (NSW 58087).

= *Utricularia pachyceras* O.Schwarz, *Feddes Repert.* 24: 98 (1927).

Type: 6 km NE of Darwin, N.T., *F.A.K.Bleeser 212*; holo: B (destroyed – *fide* Taylor 1989).

Medium to large sized annual, terrestrial herb. ***Rhizoides*** capillary, simple, up to 10 mm long, 0.45 mm thick at base tapering to 0.15 mm near the apex, numerous from the peduncle base, few from stolon nodes. ***Stolons*** few, filiform, 0.2–0.3 mm thick, internodes 4–6 mm long. ***Leaves*** few, rarely at peduncle base and 1 or 2 on stolon nodes, petiolate, lamina oblanceolate to spathulate, 2.5–4.3 mm long, 1–2.1 mm wide, single nerve, apex rounded, total length up to 5–6.5 mm long. ***Traps*** stalked, ovoid, 1.5–3.3 mm long; 1 or 2 from the base of the peduncle and nodes; uniform, mouth lateral with a simple dorsal appendage 1–3 mm long, and two simple lateral appendages 1–2.3 mm long, ventral wings absent. ***Inflorescence*** solitary, 120–310 mm long; peduncle erect, hollow, terete, glabrous, 0.9–1.8 mm thick; ***Scales*** absent; ***Bract and bracteoles*** equal, basifixed, sparsely glandular, obovate, apex rounded 1.7–2.0 mm long, c. 1 mm wide. ***Flowers*** solitary; ***Pedicel*** erect, remaining erect post-anthesis, filiform, tapering and dorsiventrally compressed apically, 5–8.5 mm long. ***Calyx*** lobes unequal; upper lobe ovate or obovate, 2.8–4.4 mm long, 2–3.1 mm wide; lower lobe shorter, depressed-ovate, with apex emarginate 2–2.4 mm long, 2.4–4 mm wide. ***Corolla*** 15–27 mm long, upper side purple or violet, underside dark maroon; ***upper lip limb*** constricted near the base, 8–15 mm long, superior part obovate or oblanceolate with apex emarginate, inferior part ovate with margin ciliate; ***lower lip limb***, flabellate in outline, 6–13 mm long, 11–24 mm wide, apex rounded; base of lower lip white near pallet rim with central yellow or orange patch; ***spur*** projecting parallel to the lower lip, to ascending at c. 30°, tetragonal in cross-section at the base, tapering to a dorsi-ventrally flattened, retuse apex, 5–6.1 mm long, c. 3.3 mm wide near base, c. 3/4 to equal or slightly longer than the length of lower lip. ***Capsule*** globose, 3.3–6.2 mm in diameter, dehiscing from a longitudinal, dorsi-ventral, non-thickened slit. ***Seeds*** cylindrical, 0.85–1.25 mm long. ***Pistil*** c. 2.3 mm long; ***Filaments*** curved c. 2.1 mm long. ***Pollen*** 3-colporate, c. 35 x 28 μ, (*Holtze s.n.*, 27. Iii. 1904, NSW) (Taylor 1989). Figures 1a–b, 2, 3; Taylor (1989), fig. 21: 1–3, 11 (from *Holtze s.n.*).

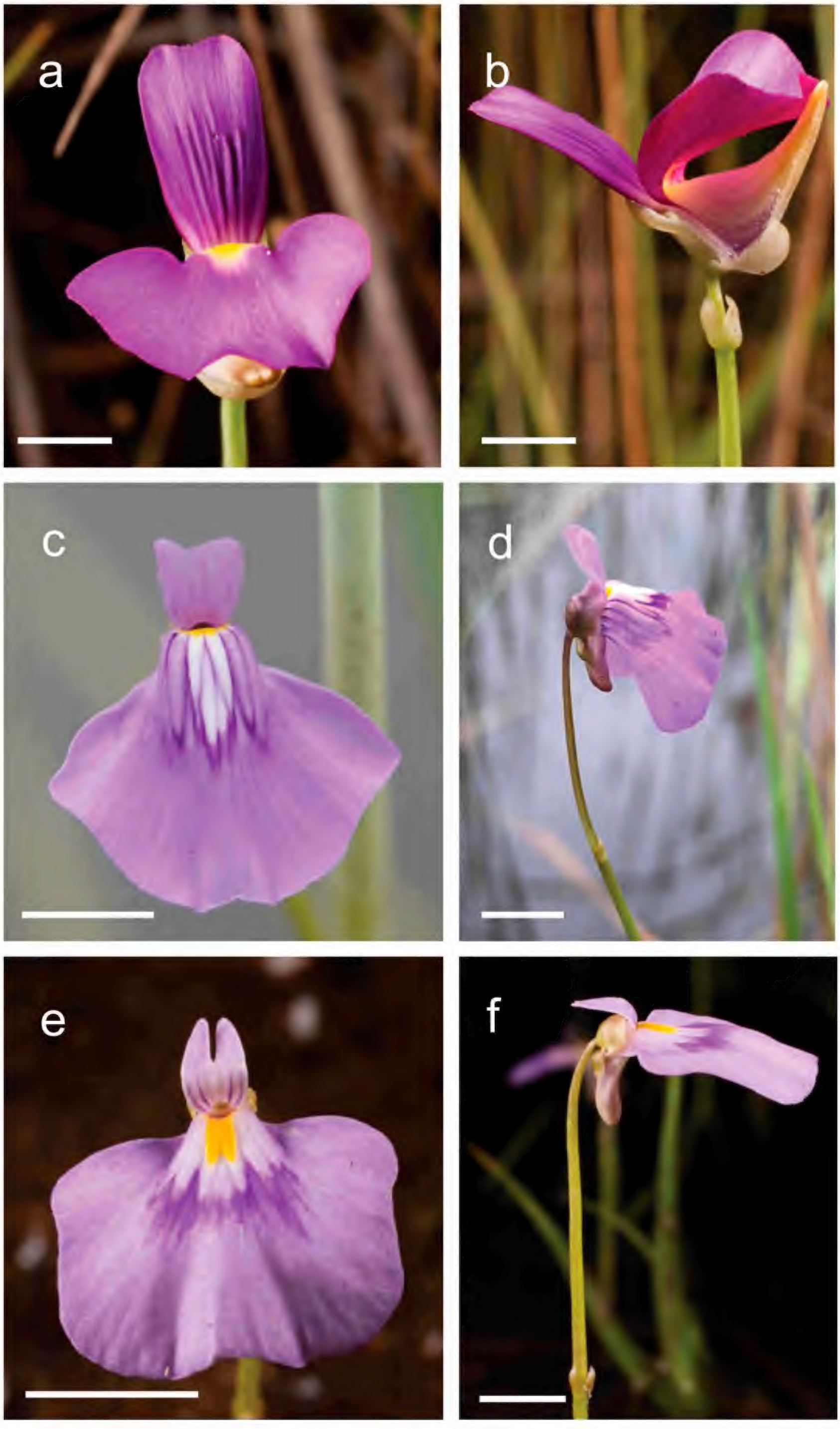

Fig. 1. *Utricularia singeriana* (a, b), *U. baliboongarnang* (c, d) and *U. hamiltonii* (e, f): a, c & e, corolla frontal view; b, d & f, corolla lateral view. Scale bars: a–f = 30 mm. Images: a, b, e & f by W. Cherry; c & d by P.C. Baleeiro.

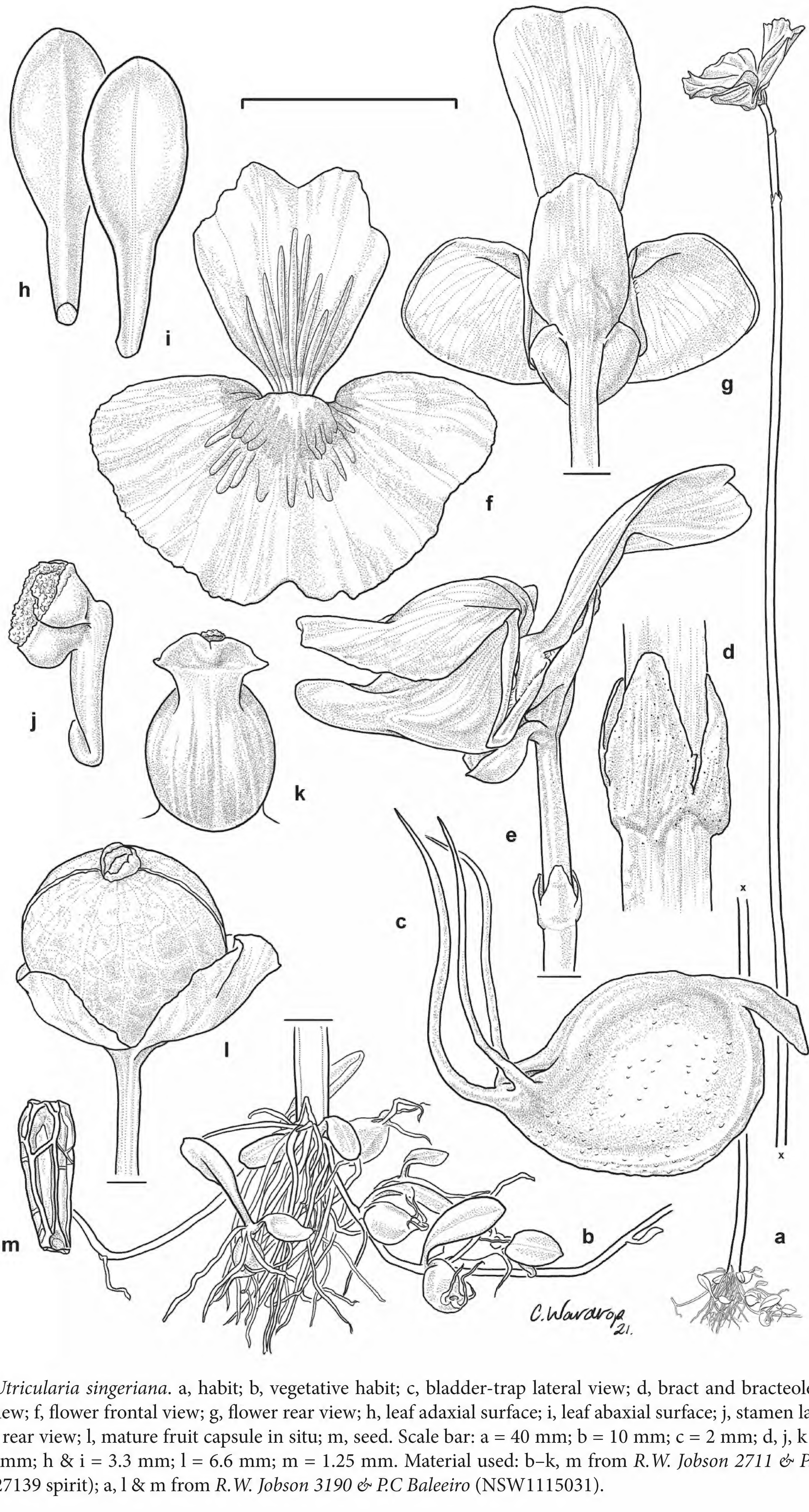

Fig. 2. *Utricularia singeriana*. a, habit; b, vegetative habit; c, bladder-trap lateral view; d, bract and bracteole; e, flower lateral view; f, flower frontal view; g, flower rear view; h, leaf adaxial surface; i, leaf abaxial surface; j, stamen lateral view; k, ovary rear view; l, mature fruit capsule in situ; m, seed. Scale bar: a = 40 mm; b = 10 mm; c = 2 mm; d, j, k = 2.5 mm; e–g = 8 mm; h & i = 3.3 mm; l = 6.6 mm; m = 1.25 mm. Material used: b–k, m from *R.W. Jobson 2711 & P.C Baleeiro* (NSW927139 spirit); a, l & m from *R.W. Jobson 3190 & P.C Baleeiro* (NSW1115031).

Fig. 3. Holotype of *Utricularia singeriana* F.Muell. (*M.Holtze 1026*; MEL 1513939).

Additional specimens examined. Northern Territory [precise localities withheld for conservation reasons]: near Darwin, *M. Holtze s.n.* 27 Mar 1904 (NSW 58087); Edith River, *C. Michell 2699*, 11 May 2000 (DNA); Nitmiluk National Park, *A. Gibbons 41*, 26 Mar 2002 (DNA); Marrawel Plateau, *K. Brennan 6535*, 17 Apr 2005 (DNA); towards Jabiru, *D.E. Murfet 6472 & A. Lowrie*, 7 Apr 2009 (AD); Finnis River, *I. Cowie 12540*, 23 May 2010 (DNA); Weddell area, *B. Stuckey 749*, 2 May 2011 (DNA); Road to Oenpelli, *R.W. Jobson 2216 & P.C. Baleeiro*, 19 Apr 2014 (NSW 852225); Weddell, *R.W. Jobson 2711 & W.A. Cherry*, 20 Apr 2015 (NSW 927139); Litchfield National Park, *I. Cowie 14076*, 20 Mar 2016 (DNA).

Distribution, Ecology & Phenology. Occurs in the vicinity of Darwin, Jabiru, Finnis River and Edith River areas of the Northern Territory (Fig. 5). The recent collection from Groote Eylandt (*Cowie 14804*) suggests that the distribution may be wider across Arnhem Land and nearby islands. Grows in wet sand and boggy seepage in swamps and near creeks. Flowers from March to June (Taylor 1989).

Conservation Status. Considered Vulnerable under Northern Territory legislation. Although the species has a wide distribution across the Darwin region, populations are locally restricted.

Notes. When observed in the field the morphologically distinct *U. singeriana* is unlikely to be confused with any other species (Fig. 1 a–b, 2, 3). According to Cowie (2010), Peter Taylor probably did not observe this species during his trip to northern Australia and instead was limited to the faded 1890 sheet specimen of *Holtze s.n.* It is likely this is the reason he included the very different material from Western Australia (i.e., *Glover 81* (sic 82)) in his description of *U. singeriana* (Taylor 1989).

Utricularia baliboongarnang Baleeiro & R.W.Jobson, ***sp. nov.***

Type: AUSTRALIA: WESTERN AUSTRALIA: East Kimberley [precise locality withheld for conservation reasons]: Racecourse Swamp, SE of Kununurra, *R.W. Jobson 3999 & PC. Baleeiro*, 25 March 2021 (holo: NSW 834760 - spirit).

Diagnosis: Similar to the distantly related *U. byrneana* in overall corolla appearance but differing in its longer inflorescence (120–370 mm vs 60–170 mm) and bladder traps with ventral wings present. Also similar to the closely related *U. hamiltonii* in having spur always less than half the length of the corolla lower lip and leaf apex acuminate, but differs in having corolla upper-lip limb emarginate or shallowly bilobed with lobes apically rounded, corolla lower lip limb obovate with 3 or 4 raised white ridges at base, and a slight deflexing of the peduncle post anthesis.

Medium sized possibly perennial, affixed aquatic herb. ***Rhizoides*** capillary, simple, up to 12 mm long, 0.6 mm thick at base tapering to 0.1 mm near the apex, numerous from the peduncle base, few from stolon nodes. ***Stolons*** few, filiform, 0.21–0.29 mm thick, internodes 7–10 mm long. ***Leaves*** few, 1 or 2 from base of peduncle, in pairs at stolon node, petiole not obvious (c. 3–6 mm long), lamina linear, 6–16 mm long, 0.3–0.75 mm wide, single nerve, apex acuminate, total length 9–22 mm long. ***Traps*** stalked, ovoid, 1.5–3.0 mm long; 1 from the base of the peduncle, 1 or 2 from nodes; dimorphic, mouth lateral with one simple dorsal appendage c. 2 mm long, and two simple lateral appendages c. 1.5 mm long, ventral wings c. 1 mm long or sometimes absent, margin usually entire. ***Inflorescence*** solitary, 120–370 mm long; peduncle erect, hollow, terete, glabrous, 0.5–1.1 mm thick. ***Scales*** absent; ***Bract and bracteoles*** equal, basifixed, sparsely glandular, narrowly ovate, apex acute 1.5–2.0 mm long, c. 0.7 mm wide. ***Flowers*** solitary; ***Pedicel*** erect, shortly deflexed post-anthesis, filiform, tapering and dorsiventrally compressed apically, 7–13 mm long. ***Calyx*** lobes unequal; upper lobe broadly ovate, 2.6–3.4 mm long, 1.8–2.5 mm wide; lower lobe smaller, orbicular, with apex emarginate 1.9–2.6 mm long, 1.7–2.3 mm wide. ***Corolla*** 12–21 mm long, pale violet-blue (Periwinkle blue); ***upper lip limb*** constricted near the base, 5.5–6.2 mm long, superior part obovate with apex emarginate or shallowly bilobed, inferior part ovate with margin ciliate; ***lower lip limb***, transversely elliptic in outline, 11–14 mm long, apex rounded; base of lower lip with 2 or 3 pale violet-blue ridges either-side of 3 or 4 central white ridges, all bordered marginally by a darker violet band, with yellow throat; ***spur*** conical at the base with apex obtuse, 4–5 mm long, c. 2 mm wide, c. 1/3 the length of lower lip. ***Capsule*** globose, c. 3.2 mm in diameter, dehiscing from a single longitudinal, ventral, marginally thickened slit. ***Seeds*** cylindrical, 0.7–0.8 mm long (immature). ***Pistil*** c. 1.4 mm long; ***Filaments*** curved c. 1.4 mm long. ***Pollen*** 3-colporate, c. 30 x 30 μ, *Jobson 3999* (NSW). Figures 1c–d, 4; Taylor (1989), fig. 21: 4–10 (from *Glover 81* (sic 82)).

Etymology. The epithet was selected in consultation with Miriwoong Elders and senior speakers of the Mirima Dawang Woorlab-gerring Language and Culture Centre. In the Mirriwoong Language the word Baliboong refers to a swamp habitat, and their word *baliboo-ngarnang* (sic) literally means "swamp-dwelling".

Fig. 4. *Utricularia baliboongarnang*. a, vegetative habit; b, habit; c, bracts and bracteoles; d & e, bladder-trap lateral view; f, leaf dorsal view; g, fruit capsule lateral view; h, flower frontal view; i, flower lateral view. Scale bars: a = 10 mm; b = 80 mm; c, d & e = 2 mm; f & g = 3.3 mm; h & i = 8 mm. Material used: All from *R.W. Jobson 3999 & P.C Baleeiro* (NSW834760 spirit).

Additional specimens examined. Western Australia [precise localities withheld for conservation reasons]: S of township of Kununurra, *C. Glover 81*, 1 Apr 1982 (PERTH); [precise locality withheld for conservation reasons], SSE of Kununurra, *K. Paijmans 2309*, 10 Mar 1978 (CANB); SE of Wyndham, *K. Paijmans 2532*, 17 Mar 1978 (CANB).

Distribution, Ecology & Phenology: Known only from two sites in the East Kimberley region near Wyndham and Kununurra, Western Australia (Fig. 5). Grows in wet sand in large seasonal swamps (Fig. 6). Flowers March to April.

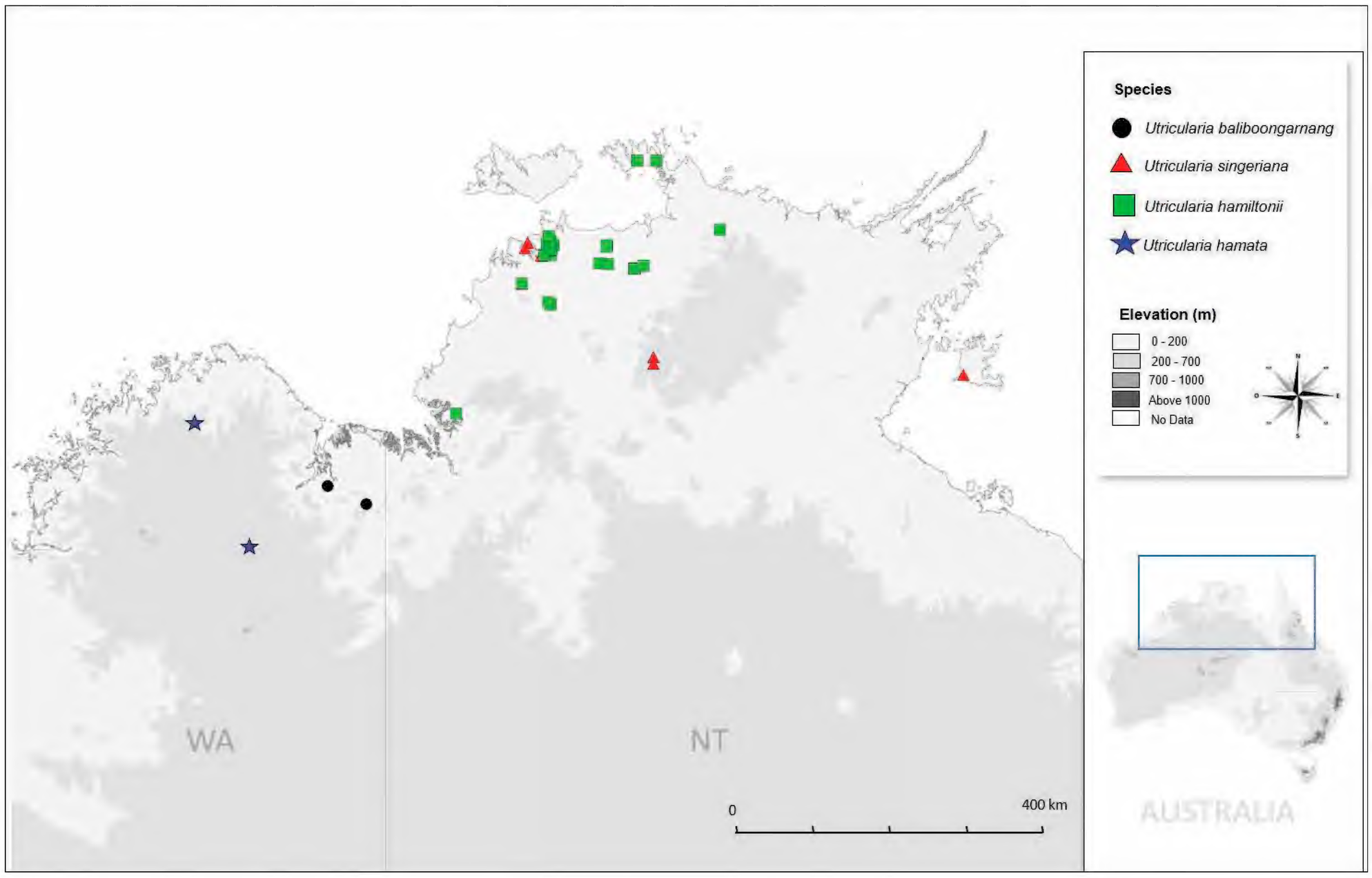

Fig. 5. Map of the Top End and Kimberley region showing the distribution of *Utricularia baliboongarnang* (black circle), *U. singeriana* (red triangle), *U. hamiltonii* (green square), and *U. hamata* (blue star).

Conservation status: This rarely collected species is known from two sites. It is listed as a Priority 2 taxon under its manuscript name *U. sp.* Kununurra (C.Glover 81). One of the sites is protected within the Parry Lagoon Nature Reserve, while the other occurs on non-conservation managed lands near Kununurra. Although there have been numerous searches for this taxon, ours was the first to record it at Kununurra since the original two collections in 1978 and 1982. Although our survey involved a broad search of a large wetland system south of Kununurra (Fig. 5), we uncovered only a few small colonies in a single small area (c. 5 m^2) of the swamp. A thorough survey of the Parry Lagoon site was not possible due to presence of saltwater crocodiles, and no plants were observed from several safe vantage points. Until a thorough search of the area is conducted, we recommend that the current conservation code P2 be maintained to reflect the observed rarity and limited known distribution of this species.

Notes: Taxonomic descriptions and illustrations of *U. singeriana* provided in Taylor (1989) combine *Utricularia baliboongarnang* (*Glover 81* (sic '82')), fig. 21: 4–10) and *U. singeriana* (*Holtze s.n.*, 1–3, 11). The phylogeny of Jobson *et al.* (2017) placed two accessions of *U. baliboongarnang* (as *U.* sp. Kununurra (C.Glover 81) R.W.Jobson) from Kununurra and Wyndham, WA as nested within a clade containing accessions of the Northern Territory *U. hamiltonii* (Fig. 1e–f) with this clade in turn sister to accessions of *U. hamata* (Jobson *et al.* 2017). All three of these species share the affixed aquatic habit, although the smaller stature of *U. hamiltonii* limits it to very shallow habitats (Taylor 1989). *Utricularia baliboongarnang* is similar to *U. hamiltonii* in having spur always less than half the length of the corolla lower lip (Fig. 1c–f) and leaf apex acuminate. The most salient differences between *U. baliboongarnang* and *U. hamiltonii* are inflorescences medium sized (120–370 mm long) vs. small or very small (50–100 mm long), having corolla upper-lip limb emarginate or shallowly bilobed with lobes apically rounded vs. deeply divided lobes that are apically acute, corolla lower lip-limb obovate with

3 or 4 raised white ridges at base vs. corolla lower lip-limb quadrate, with a yellow patch at base, and a slightly vs. strongly deflexing of the peduncle post anthesis (Taylor 1989). *Utricularia baliboongarnang* differs from *U. hamata* (Jobson *et al*. 2018) in having a pale violet-blue corolla vs. mostly white, and a corolla upper lip limb with six purple streaks above middle vs. four (Fig. 4).

Fig. 6. Habitat of *U. baliboongarnang* from Kununurra, WA (type site). **a,** habit; **b,** habitat. Images: all by P.C. Baleeiro.

The flowers of *Utricularia baliboongarnang* (Figures 1a,b; 4) are similar to those of the West Kimberly *U. byrneana* R.W.Jobson & Baleeiro (Jobson and Baleeiro 2015), although their phylogenetic relationship is distant (Jobson *et al.* 2017). Despite the superficial floral similarity, the inflorescence of *U. baliboongarnang* is longer (120–370 mm long) than those of *U. byrneana* (60–170 mm long), the peduncle is solid (vs. hollow), and the traps bear three long simple appendages and an absence of the ventral wings in *U. byrneana* (Jobson *et al.* (2015).

Key to related species (sect. *Pleiochasia*) from northern Australia, modified from Jobson (2012)

(Abbreviations: N.T. = Northern Territory; Qld = Queensland; W.A. = Western Australia)

1a. Peduncle solid; lower lip of corolla mauve with conspicuous ridges at base, central ridges yellow ..... ***U. byrneana*** (W.A.)

1b. Peduncle hollow 2

2a. Freely suspended aquatic; leaves verticillate, narrowly linear; peduncle inflated; corolla very pale pink with a very slender spur, 1.5–2 cm long..... ***U. tubulata*** (W.A., N.T., Qld)

2b. Terrestrial, affixed- or sub-aquatic; leaves not verticillate 3

3a. Inflorescence 1.6–5 cm long 4

3b. Inflorescence 9–50 cm long 5

4a. Corolla white/yellow, spur straight, shorter or slightly longer than the lower-lip..... ***U. albiflora*** (Qld)

4b. Corolla pale violet, spur curved, 1.3–2 times longer than the lower lip ..... ***U. limmenensis*** (N.T.)

5a. Leaf apex acuminate 6

5b. Leaf apex acute to rounded..... 8

6b. Corolla white or very pale violet ..... ***U. terrae-reginae*** (Qld)

6b. Corolla violet or pale violet-blue..... 7

7a. Corolla upper-lip apex emarginate or shallowly bilobed, lobes apically rounded; lower lip transversely elliptic ..... ***U. baliboongarnang*** (W.A.)

7b. Corolla upper lip apex deeply bilobed, lobes apically acute; lower lip quadrate ..... ***U. hamiltonii*** (N.T.)

8a. Spur of corolla subulate, with apex acute..... 9

8b. Spur of corolla conical or tetragonal in cross section, with apex obtuse 10

9a. Corolla mauve with slightly raised white 5-lined blotches at base of lower lip ..... ***U. triflora*** (N.T.)

9b. Corolla light violet with five prominently raised white ridges at base of lower lip ..... ***U. blackmanii*** (Qld)

10a. Corolla purple-violet; lower lip equal length or shorter than spur ..... ***U. singeriana*** (N.T.)

10b. Corolla white; subaquatic emergent habit 11

11a. Flowers solitary; corolla upper lip with four vertical purple streaks..... ***U. hamata*** (W.A.)

11b. Flowers usually 2–5; corolla upper lip entirely white..... 12

12a. Corolla lower lip with yellow patch at the base..... ***U. linearis*** (N.T.)

12b. Corolla lower lip with 5–7 slightly raised yellow ridges at the base ..... ***U. fistulosa*** (W.A.)

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Diospyros venablesii W.E.Cooper (Ebenaceae), a new and endemic species from the Iron Range area, Cape York Peninsula, Queensland

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Abstract

Diospyros venablesii W.E.Cooper is described and illustrated with notes on habitat, distribution and how to distinguish it from the most similar species, *Diospyros laurina*.

Introduction

Diospyros L. is a pantropical genus of *c*. 550 species (Mabberley 2017) belonging to the family Ebenaceae. The Indopacific holds the largest diversity with *c*. 250 species. In Australia *Diospyros* was recently revised by Jessup (2014) with descriptions of 22 species including *D.kaki* Thunberg, which is naturalised. Seventeen species occur within the Wet Tropics Bioregion making it the region of most diversity in Australia.

With insufficient fertile material in herbaria, *Diospyros* sp. Ham Hill (*B.Hyland 2941RFK*) was not included in that revision even though the first collection was made in 1962 (*Volck AFO 02410* [CNS]). Recent collections of both flowering and fruiting material have now made a formal description possible and herein *Diospyros venablesii* W.E.Cooper is described and named as a new species for the rainforests of the Iron Range area on Cape York Peninsula.

Materials and methods

The study is based upon the examination of herbarium material from BRI and CNS, as well as field observations. All specimens cited have been seen by the author apart from those indicated *i.d.v.* (*imago digitalis visa*), that have been examined digitally from BRI.

Measurements of the floral parts and fruits are based on material preserved in 70% ethanol as well as fresh material from the field.

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Taxonomy

Diospyros venablesii W.E.Cooper ***sp. nov.***

Type: Australia: Queensland: Cook District: Road Reserve, Portland Roads Road, adjacent to Iron Range National Park, 31 August 2021, *W.Cooper 2779, J.Pritchard & E.Joyce* (holo: CNS 151007 [3 sheets + spirit CNS 151007. + spirit]; iso: 2 sheets each to be distributed to BRI, CANB & MEL, one sheet each to be distributed to K, L, MO, SING).

Diospyros sp. (Ham Hill B.Hyland 2941RFK), Jessup *et. al.* 2016; *Zich et. al.* 2018

Illustrations: Zich *et al.* (2018) as *Diospyros* sp. Ham Hill (B.Hyland 2941RFK)

Tree to 10m, dioecious; bark blackish and shallowly textured with numerous elongated horizontal fissures and lenticels; twigs with basifixed appressed silvery hairs becoming glabrous. New growth pink. *Leaves* simple, alternate: petioles 3–5 mm long, glabrescent; lamina elliptical, 30–118 mm long, 18–48 mm wide, thinly-leathery, base cuneate; apex shortly acuminate, acute or obtuse; margin entire, flat; both surfaces thinly sericeous with sparse appressed hairs; underside with 3–8 scattered black glands, discolorous; venation brochidodromous, midrib shallowly depressed on adaxial surface and raised on abaxial surface, lateral veins 5–8 pairs, tertiary venation reticulate and obscure. *Inflorescences* axillary or terminal, fragrance not detected. *Male inflorescence* a raceme up to 15 mm long; 2–8-flowered; rachis silvery pubescent; bracts at rachis base and flower bases similar, broadly ovate, *c.* 1.25 mm long, *c.* 1.25 mm wide, silvery pubescent abaxially and glabrous adaxially; flowers sessile. *Calyx* cupular, *c.* 2 mm long, 1.5 mm wide, silvery pubescent abaxially and glabrous adaxially, white, shallowly 3-lobed. *Corolla* tubular, 7.5–8 mm long, *c.* 2.75 mm wide, lobes 3, recurved and acute, *c.* 1.75 mm long, silvery pubescent abaxially and glabrous adaxially, pale green to white. *Stamens* 2 or 3, 5.5–6 mm long; filaments free (not adnate to tube), 2.5–3.5 mm long, glabrous; anthers linear, 2.5–2.8 mm long; pistillode globose-ovoid, *c.* 1.3 mm long, silvery hirsute. *Female inflorescence* a solitary flower; bracts at base paired, oblong-ovate, 2–3.25 mm long, silvery puberulent abaxially and glabrous adaxially. *Flowers* sessile or with a peduncle to 1 mm long. *Calyx* campanulate, 6.5–8 mm long, silvery puberulent both abaxially and adaxially, 3-lobed, lobes rounded, firm, *c.* 1 mm thick, ribbed, greenish-yellow. *Corolla* tube broadly ovoid, 7.5–8 mm long and 7–7.5 mm wide, lobes 3, recurved, broadly triangular, 2–2.5 mm long and *c.* 3 mm wide at base, silvery puberulent abaxially and glabrous adaxially, white. *Ovary* subglobose, *c.* 2.5 mm long and 3.5 mm wide, silvery puberulent, 3-locular, ovules 2 per locule, style *c.* 1 mm long, sparsely puberulent; stigma up to 12-lobed, diameter *c.* 1.25 mm. *Fruit* sessile, a berry, globose, 20–25.5 mm long, 24–29 mm wide, apex distinctly truncated and a very short persistent stigma, stigma diameter *c.* 1.5 mm, yellow, indumentum of appressed sericeous hairs over most of the fruit, more densely so proximally; calyx persistent at base, 13–17 mm diameter, thick, firm, recurved, 3-lobed, lobes broadly rounded, abaxially sericeous to sparsely sericeous, adaxially densely sericeous. *Seeds* 2–6, canoe-shaped, brown, *c.* 12 mm long, *c.* 6 mm wide. Germination epigeal. (Figures 1, 2 & 3)

Diagnosis: *Diospyros venablesii* is similar to *Diospyros laurina* (R.Br.) Jessup but differs by having: indumentum silvery (vs pale rusty); leaf texture thin and sub-membranaceous (vs thick and coriaceous); leaf apex shortly acuminate, acute or rarely obtuse (vs obtuse, rounded or rarely acute); pistillate corolla broadly ovoid and equidimensional (vs narrowly ovoid with the width equal to about half the length); fruiting calyx recurved from base and not enclosing fruit (vs slightly recurved at apex and enclosing the basal 1/3 to 1/2 of the fruit); fruit dimensions wider than long (vs longer than wide); fruit diameter 24–29 mm (vs 12–16 mm); fruit apex truncate (vs rounded).

Fig. 1. *Diospyros venablesii*. Male flowers (Voucher: *Cooper 2784*, CNS). Photo E. Joyce.

Fig. 2. *Diospyros venablesii*. Female flower (Voucher: *Cooper 2779*, CNS). Photo E. Joyce.

Fig. 3. *Diospyros venablesii*. Fruit (Voucher: *Cooper 2745*, CNS). Photo W. Cooper.

Distribution: *D.venablesii* has only been recorded in lowland rainforest between the Claudie and Pascoe Rivers in the vicinity of Kutini-Payamu (Iron Range) National Park and Iron Range Research Station on Cape York Peninsula, Queensland (Figure 4).

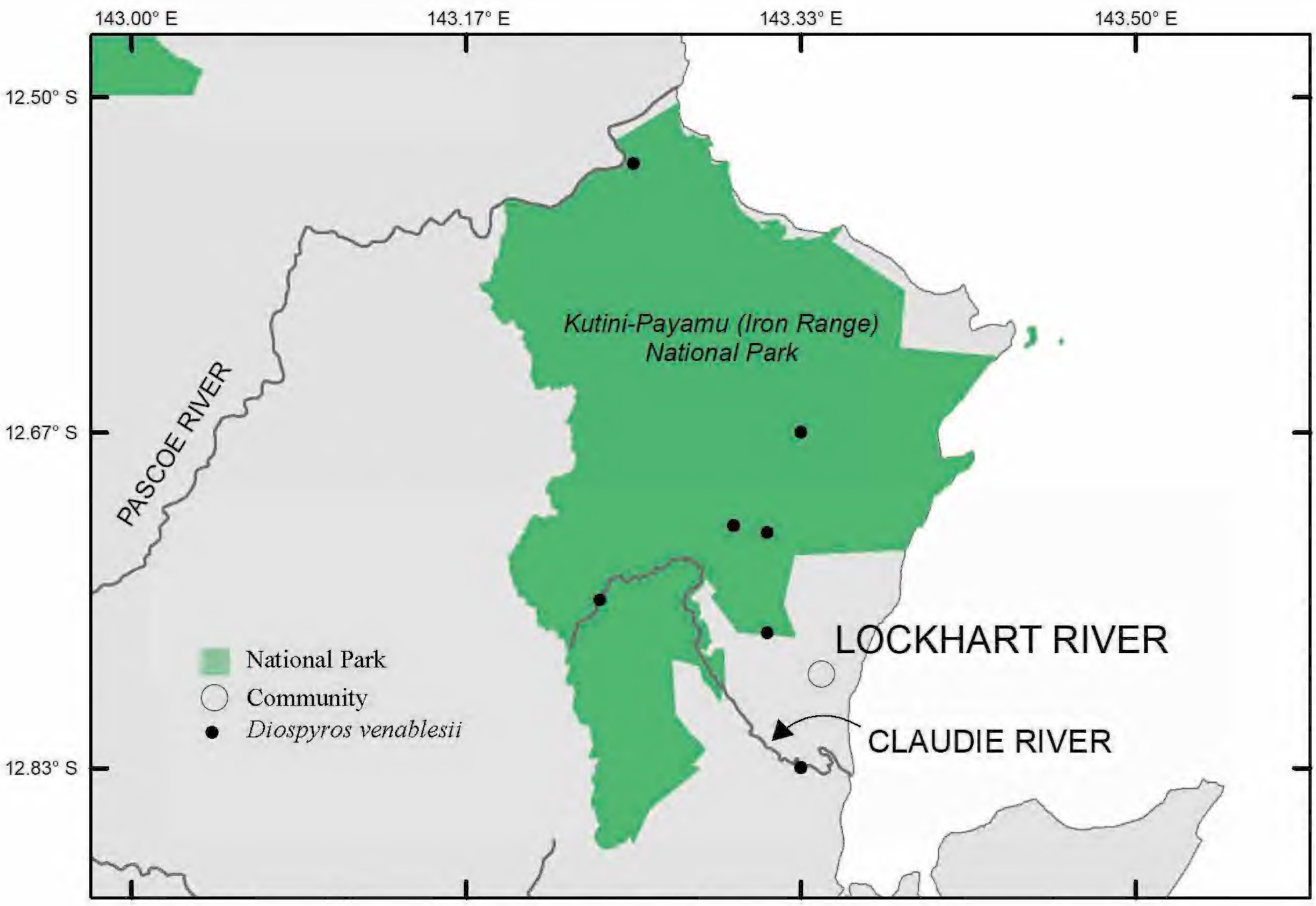

Fig. 4. Distribution map of *Diospyros venablesii* in the vicinity of Kutini-Payamu National Park, Cape York Peninsula, Queensland, Australia.

Habitat and Ecology: This species grows as a sub-canopy tree in semi-deciduous complex mesophyll and notophyll vineforest. It co-occurs with *Aglaia argentea* Blume, *Aleurites moluccanus* (L.) Willd., *Antiaris toxicaria* var. *macrophylla* (R.Br.) Corner, *Argyrodendron polyandrum* L.S.Sm., *Barringtonia calyptrata* (R.Br. ex Miers) R.Br. ex F.M.Bailey, *Beilschmiedia obtusifolia* (F.Muell. ex Meisn.) F.Muell., *Berrya javanica* (Turcz.) Burret, *Buchanania arborescens* (Blume) Blume, *Canarium australianum* F.Muell., *Castanospermum australe* A.Cunn. & Fraser ex Hook., *Garuga floribunda* Decne. var. *floribunda*, *Margaritaria dubium-traceyi* Airy Shaw & B.Hyland, *Myristica insipida* R.Br., *Neolamarckia cadamba* (Roxb.) Bosser, *Neonauclea glabra* (Roxb.) Bakh.f. & Ridsdale, *Premna hylandiana* Munir, *Syzygium pseudofastigiatum* B.Hyland, *Terminalia sericocarpa* F.Muell., *Tetrameles nudiflora* R.Br. and *Zanthoxylum rhetsa* (Roxb.) DC. Altitudinal range is from near sea level to about 50 m.

Phenology: Flowers have been recorded in August, September and October and fruit has been recorded in December and January.

Etymology: *Diospyros venablesii* is named for Brian Lewis Venables (1947–), a raconteur and naturalist who often resides on eastern Cape York Peninsula. He has been very helpful to me and to many biologists studying flora or fauna especially in the Iron Range and Cairns areas and deserves recognition for his generosity and contributions.

Affinities: *Diospyros venablesii* is similar to *Diospyros laurina*. However, the numbers of lateral veins in the leaves, pistillate flower calyx lobes, pistillate corolla shape, fruiting calyx and fruit shape differ significantly. The leaves on *D. venablesii* are much thinner, the shape mostly oblong-elliptical or elliptical and with apices usually shortly acuminate vs obovate or sub-orbicular (rarely oblong-ovate) and mostly with obtuse or rounded apices.

Applying the Key to Australian species of *Diopyros* using male flowers (Jessup 2014) one would arrive at couplet 17 (*D. yandina* and *D. pluviatilis*); for the second key using female flowers one would arrive at couplet 12 (*D. laurina*).

Additional specimens seen: QUEENSLAND. Cook District: Cassowary Creek, 1.5 km from confluence with the Pascoe River, Iron Range National Park, 28 Apr. 1993, *Fell DGF3145A* & *Butcher* (BRI) *i.d.v*; Northern footslopes of Ham Hill, 7.6 km NNW of Lockhart River, 26 Mar. 1994, *Fell DGF4126* & *Stanton* (BRI) *i.d.v*; Claudie River between Portland Roads and Iron Range, 21 Oct. 1968, *Webb* & *Tracey 8589* (BRI) *i.d.v*; Near Ham Hill, Weymouth Holding, 24 Oct. 1973, *Hyland 2941RFK* (CNS); EP/42 Claudie River, 19 Nov. 1977, *Stocker 1644* (CNS); Road reserve, Portland Roads Road, adjacent to Iron Range National Park, 5 Dec. 2020, *W.Cooper 2732, R.Jensen, D.Fell, T.Hawkes & B.Venables* (CNS); Road reserve, Portland Roads Road, adjacent to Iron Range National Park, 23 Jan. 2021, *W.Cooper 2745, J.Pritchard & L.Ross*, (CNS); Road reserve, Portland Roads Road, adjacent to Iron Range National Park, 1 Sept. 2021, *W.Cooper 2785, E.Joyce & B.Venables*, (CNS); Iron Range National Park, West Claudie River, 26 Mar. 1993, *Fell DGF3074* & *Stanton* (BRI) *i.d.v*; Iron Range, Cape York region, Sept. 1962, *Volck AFO 02410*, (CNS); Waygi Ck, Iron Range Research Station (IRRS), 13 Mar. 2017, *Fell DGF IRRS215, Cook* & *Cook* (BRI) *i.d.v*; Claudie River, 11 Oct. 1972, *Hyland 2680RFK* (CNS); Claudie River, 22 Oct. 1973, *Hyland 6983* (CNS).

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Lepidosperma prospectum (Cyperaceae), a new species from Sydney coastal heath and notes on usage of sword sedges

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Abstract

Lepidosperma prospectum G.T.Plunkett & R.L.Barrett (Cyperaceae tribe Schoeneae) is here described as a new species from the Sydney region of New South Wales. It is highly restricted in distribution, occurring at Manly (Sydney Harbour National Park), Kamay Botany Bay National Park and Royal National Park in dense coastal shrublands behind coastal cliffs. These locations are within the traditional lands of the *Gamaragal*, *Gweagal* and *Dharawal* people respectively. Joseph Banks and Daniel Solander were the first Europeans to explore the flora of New South Wales in 1770 around Botany Bay but they did not collect this species. *Lepidosperma prospectum* is superficially similar to *L. sieberi* Kunth, which occurs in adjacent habitats, but molecular data have shown that it is more closely allied to Western Australian species. A brief review of recorded indigenous and European knowledge and utilisation of the genus *Lepidosperma* Labill. is presented to highlight the varied uses of the genus.

Keywords: biodiversity; indigenous knowledge; Cyperaceae; sword sedge; taxonomy; Sydney; Joseph Banks; Daniel Solander; sandstone flora; taxonomy.

Introduction

Lepidosperma Labill. (sword and rapier sedges; Cyperaceae) is one of the largest genera in the Australian flora when putative undescribed species are included. Eighty species are currently named, but up to three times this number await description (Barrett 2012b; Barrett and Wilson 2012, 2013; Barrett, 2013; Plunkett et al. 2013, 2018; Barrett & Barrett, 2015; Plunkett 2016). New species are still being discovered even in close proximity to major population centres, as exemplified by the description of three new species from Kings Park, beside the

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Perth central business district, Western Australia (Barrett and Wilson 2013; Barrett and Barrett 2015). While a number of new *Lepidosperma* species have been described in the last few decades (Wilson and Morris 1993; Wilson 1993; Barrett 2007a, 2007b; Barrett and Wilson 2013; Plunkett *et al.* 2013, 2018; Barrett and Barrett 2015), significant historical misapplication of names has led to great confusion over species concepts, especially in Western Australia (e.g. Barrett 2012a). Several studies have highlighted the difficulty in establishing species limits in complex groups such as *L. laterale* R.Br. (Gray 1994; Hodgon *et al.* 2006). A detailed nomenclatural review has resolved the application of published names (Barrett and Wilson 2012), paving the way for the description of new species. Two PhD projects have created a very detailed phylogeny for the genus based primarily on nuclear ETS DNA sequence data (Barrett 2012b; Plunkett 2016).

During fieldwork by K.L. Wilson and R.L. Barrett in Sydney Harbour National Park at Manly in 2009, a sedge population was located in tall shrubland that was thought at the time to be a tall form of *Lepidosperma sieberi* Kunth, but atypical in inflorescence form, with typical *L. sieberi* occurring nearby in more open habitats. Subsequent sequencing of the nuclear ETS region showed that despite superficial similarities to *L. sieberi*, the taxon was placed with Western Australian taxa, near *L. resinosum* (Lehm.) F.Muell. ex Benth., well-removed from *L. sieberi* (Barrett *et al.* 2012). A check of collections at NSW located one previous collection, made by K.L. Wilson, from Royal National Park in 1992. This collection had been confused with *L. concavum* R.Br. which occurs near all known locations of *L. prospectum*. This taxon was subsequently given the informal phrase name *Lepidosperma* sp. Blue Fish Point (R.L. Barrett & K.L. Wilson RLB 5554). The phylogenetic position resolved by Barrett *et al.* (2012) was confirmed by Plunkett (2016) with a broader sampling of eastern Australian *Lepidosperma* taxa, and a description was drafted in DELTA. Following additional field observations by R.L. Barrett in Kamay Botany Bay National Park (2019) and at a second location in Royal National Park (2020), we here describe the taxon as a new species, *Lepidosperma prospectum* G.T.Plunkett & R.L.Barrett.

Lepidosperma prospectum occurs in tall coastal heath or low woodland ('Sydney Coastal Heaths'; Keith 1994 or 'heath on the dunes'; Bear 2010) behind the sandstone sea-cliffs, in relatively dense vegetation that provides a high degree of shading. This contrasts with the two species that *L. prospectum* has been confused with, *L. concavum* and *L. sieberi*, which both occur nearby, but in low, open heath. Many coastal vegetation communities in New South Wales have been impacted by extensive clearing for urban and agricultural development (Benson and Howell 1990; Fairley 2004), but all known populations of *L. prospectum* are in National Parks where the native vegetation remains in very good condition.

Traditional knowledge and utilisation of *Lepidosperma*

Lepidosperma species are critical components of many southern Australian ecosystems and play a key role in community ecology (Barrett 2013). A global review of economic usage of Cyperaceae has been provided by Simpson and Inglis (2001). However, there are numerous uses of *Lepidosperma* recorded in more obscure literature sources and more recent literature that were not available to them (Table 1). Most usage involves the leaves or culms for weaving or fibre production, often for quite elaborate purposes, but some species were also used for food by both indigenous and European Australians (who presumably gained their knowledge from local indigenous people; see Clarke 2008; Olsen and Russell 2019), and these records are summarised in Table 1. Use as a fibre plant and in weaving was very widespread prior to the introduction of alternative materials by Europeans, but identifying records in the European literature is hampered greatly by the fact that most European observers did not identify the plants beyond 'rush' or 'sedge'; a taxonomic impediment at a community level that remains common today. A reference to grass 'with edible parts' (Andrews *et al.* 2017) is more likely a reference to a sedge (or possibly a *Lomandra*), but quite possibly to *Lepidosperma*, which is very 'grass-like' in appearance. Aboriginal people often had quite detailed taxonomies for plants, based on functional groups (Waddy 1988 and see the classification of eucalypts in Bodkin and Robertson 2013), but often only communicated the top-level taxonomy until they were confident the listener had understood them. Most identifiable observations relate to the most widespread and recognisable species, *L. gladiatum* and *L. laterale s. lat*. (e.g. Gott 1993; Cahir *et al.* 2018).

Table 1. Human utilisation of *Lepidosperma* species.

Species	Part used	Usage	People	Region	Name	Refs
L. avium K.L.Wilson	culms	probably basketry	*Yankunytjatjara*	Everard Ranges	*puta-puta*	1
L. calcicola R.L.Barrett & K.L.Wilson	plants	soil stabilisation	Europeans	coastal WA		2
L. canescens Boeckeler	culms	eel trap, fish trap, yabbie trap, turtle-form basket	*Ngarrindjeri*	lower Murray River, SA	*pinki-moranyi*	3, 4
L. canescens, L. viscidum R.Br.	culms	mats, craft items	Aboriginal	SE Australia		5
L. elatius Labill.	culms	basketry	Aboriginal	Vic.		6
L. elatius, L. laterale R.Br. *s. lat.*	culms	fibre	Aboriginal	dry rainforests in NSW	-	7
L. elatius	culms	paper	European			8
L. filiforme Labill.	culms	basketry	Aboriginal	Wimmera, Vic.	-	9
L. filiforme	culms	basketry	Aboriginal	Tas.		11
L. ensiforme (Rodway) D.I.Morris, *L. gladiatum* Labill., *L. sieberi* Kunth (as *L. concavum* R.Br.)	culms	basketry	*Nueonne*	Bruny Island, Tas.	-	13
L. gladiatum	culm base, culms	food, basketry	Aboriginal	Tas.	-	6, 11, 12
L. gladiatum	culm base	food	Aboriginal	SA	-	6
L. gladiatum	culms	paper	European	Vic.	-	8, 9, 13–15
L. gladiatum	leaves, culms, rhizomes	food, basketry, rope, string, treating colds	*Nyoongar*	coastal WA	*kerbein*	16, 17, 18
L. gladiatum	culms	vegetable	European	southern WA		19
L. gladiatum	plants	soil stabilisation	Europeans	coastal WA		2
L. gladiatum	culms	mats, basketry, food, moisture	*Ngarrindjeri*	Coorong, SA	*ngrakani, thyuk, wingi, winggi*	4, 20–23
L. gladiatum	culms	paper	European	Coorong, SA		20
L. gladiatum	culms	hats	European	NSW		24
L. laterale s. lat.	culms	basketry	*Kulin*	Vic.	-	6, 12
L. longitudinale Labill.	culms	mat weaving	*Minjerribah Moorgumpin*	North Stradbroke Island, Qld	-	25
L. longitudinale	culms	paper	European			8
L. sieberi (as *L. squamatum* Labill.)	culms	table mat	Aboriginal	Wimmera, Vic.	-	9, 13
L. viscidum R.Br.	culms	basketry	*Ngarrindheri*	Coorong, SA	*kikandu*	4

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European interpretations of the nature and usage of manufactured items reflect commonly held assumptions that the designers were part of a 'primitive' society rather than members of the oldest surviving civilisation, influencing the way in which these items are recorded. Examination of some of the specific items made using sedge fibres provides insights into the complexity and nature of the civilisation that produced them. The *Ngarrindjeri* people along the lower Murray River in South Australia used *pinki-moranyi* (*Lepidosperma canescens* Boeckeler) to make a range of complex traps for catching fish, eels and yabbies, as well as highly artistic baskets including in the form of a turtle (Clarke 2003; MAAS 2020). Across southern Australian indigenous communities, woven items, including table mats, basketry items, crafts and toys, were commonly

made from flat-leaved *Lepidosperma* species, or from derived fibres, as they were very durable (Anonymous 1895; Campbell *et al.* 1946; Clarke 1986, 1999, 2003, 2007, 2015; McCourt and Mincham 1987; Bonney 2004; Stephens and Sharp 2009).

The known locations for *Lepidosperma prospectum* are within the traditional lands of the *Gamaragal*, *Gweagal* and *Dharawal* people (Tindale 1974; Mulvaney and White 1987; Troy 1994). While no specific records of utilisation have been found (e.g. Bodkin and Robertson 2013; Andrews *et al.* 2017), it is likely that *Lepidosperma prospectum* was utilised for fibre and weaving, similarly to *Lomandra longifolia* Labill., and the leaf bases may have been chewed when fresh water was scarce. Fishing was a very important source of food for Indigenous people in coastal regions around Sydney. *Dharawal* women made hand fishing lines using hair or plant fibres including twine made from *Livistona australis* (R.Br.) Mart. (Bursill *et al.* 2007), the stringybark *Eucalyptus agglomerata* Maiden or *Ficus rubiginosa* Desf. ex Vent. (Andrews *et al.* 2017), and fibre from *Lepidosperma* may well have been used for this purpose also.

Bees are known to collect resin (to make propolis) from *Lepidosperma* sp. Montebello (aff. *viscidum*) on Kangaroo Island and this contains novel chemical compounds with potential medicinal values (Duke *et al.* 2017). Similar chemical properties are probably widespread in the genus, particularly in species producing copious amounts of resin at the base of the plant, and may have been utilised by indigenous people as traditional medicines. R.L. Barrett has heard verbal reports of the bases of *Lepidosperma gladiatum* being chewed to treat colds in southern Western Australia, similar to noted use of boiled bases to treat colds (NACC 2017). Backhouse (1843) and Irvine (1957) record that the base of the inner leaves of *L. gladiatum* are edible, with a nutty flavour. They were eaten by Aboriginal people (Abbott 1983; Hansen and Horsfall 2016, 2019) and had some use as a vegetable by early colonists in southern Western Australia (Low 1991). While specific usage is not currently recorded, *L. avium* (as *L. canescens*) is included under a traditional name for sedges, *puṯa-puṯa*, in the Everard Ranges area of central Australia and may have been used for weaving basketry in the past by the *Yankunytjatjara* people (Everard *et al.* 2002).

As a genus, *Lepidosperma* attracted considerable interest as a fibre plant during the first century of European colonisation. Several tons of *L. gladiatum* were exported from South Australia to England for paper-making trials in the 19th century (Bonney 2004). Interest was sufficiently strong that a patent application for the use of fibres from *L. gladiatum* was made in South Australia. It is noteworthy that a select committee of the Legislative Council of South Australia refused the application for exclusive rights in recognition of similar traditional usage by Aboriginal people in the region (Corbett 1861). The vigorous clonal spread of *Lepidosperma gladiatum* in coastal areas may make it amenable to cultivation and harvest as a perennial fibre crop, in addition to being valuable for dune stabilisation (though harvesting from wild populations could have similarly negative impacts). The potential of *Lepidosperma* for fibre use has been known for some time (e.g. Christy 1882, Maiden 1892, Hannan 1902); however, commercial utilisation is yet to become a reality, possibly due to challenges in cultivating plants due to seed dormancy (Panaia *et al.* 2009; Kodym *et al.* 2010; Turner *et al.* 2014) and a generally poor understanding of the ecology of the genus, despite its widespread use by Aboriginal people.

Methods

The description of the new species is based on specimens examined at NSW and in the field. Measurements and terminology follow Bruhl (1995), Barrett (2007b) and Plunkett *et al.* (2013).

Taxonomy

Lepidosperma prospectum G.T.Plunkett & R.L.Barrett, *sp. nov*.

Type: Royal National Park, Jibbon Trail, near Jibbon Head, New South Wales, 15 September 2020, *R.L. Barrett RLB 9330* (holo: NSW 1119251; iso: BM, CANB, MEL).

Lepidosperma sp. Blue Fish Point (R.L. Barrett & K.L. Wilson RLB 5554)

Large caespitose perennial 0.6–1.2 m high, 0.4–1.5 m across. *Rhizomes* spreading, to at least 30 cm long. *Culms* 65–115 cm long, 5.3–7.9 mm wide; 0.9–2.2 mm thick, biconvex to planoconvex, striate or smooth, not grooved, margins scabrous, marginal hairs continuous along blade, antrorse, evenly spaced, not resinous, faces glabrous. *Culms* longer than leaves, culm to leaf ratio ± 0.9. *Leaves* equitant, spreading at 10–20 degrees in individual ramets, 44–98 cm long. *Leaf sheath* 6–13 cm long, mid-brown, or dark brown to almost black, not conspicuously resinous, leaf sheath margins translucent, glabrous, smooth or scabrous, face glabrous. *Ligule* with a free limb, acuminate, glabrous or scabrous. *Leaf lamina* well-developed, (25–)38–87 cm long, 3.8–7.4 mm wide, 0.3–0.7 mm thick, linear, biconvex to concavo-convex, coarsely or finely striate, not deeply grooved, leaf lamina margins concolorous, not resinous, scabrous, marginal hairs continuous along blade (not interrupted), antrorse, evenly spaced, leaf lamina faces glabrous. *Involucral bract* 5–17 cm long, sheath 12–48 mm long, green, yellow-brown, pale to dark brown, or grey, not resinous, sheath apex scabrous or puberulous, lamina 38–112 mm long, 2.3–3.3 mm wide, isobilaterally flattened along entire length, or triangular in section at bract lamina apex, scabrous, not resinous, apex acuminate. *Inflorescence* narrowly ovate, or narrowly elliptic, panicle-like; 8–17 cm long, 28–34 mm wide, with 3–4 orders of branching, primary axis 7–14-noded, lowest internode 30–47 mm long, lateral branches 1 per node, spikelets somewhat distanced near the base of the inflorescence, but contracted above primary or secondary branches, lowest lateral branch 40–91 mm long, 10–30 mm wide (including spikelets). *Spikelet prophyll* emarginate, margin, keel and abaxial face puberulous. *Spikelets* 35–90 per lowest lateral branch, 7.1–9.8 mm long; 1.7–3.1 mm diam., all flowers bisexual, fertile, rachilla straight. *Sterile floral bracts* 4 per spikelet, basal bracts 3.2–4.2 mm long, apex aristate, midrib raised, mucronate, abaxial face puberulous, margins puberulous. *Fertile floral bracts* 3 per spikelet, 6.9–8.3 mm long, 1.2–1.5 mm wide, apex subulate, not mucronate, midrib apparent, abaxial face puberulous, adaxial face glabrous, margins puberulous. *Stamens* 3, filaments 4.1–6.8 mm long; anthers 2.5–3.2 mm long, 0.4–0.5 mm wide, with a glabrous apical appendage 0.9–1.1 mm long. *Style* 3-branched, undivided part 2.6–3.7 mm long, glabrous, branches 1.9–2.7 mm long, hairy. *Perianth scales* 6, 1.2–1.8 mm long, 0.4–0.7 mm wide, narrow-ovate or ovate, apex caudate or subulate with antrorse hairs, base glabrous. *Nutlet* 3.7–4.5 mm long, 2.0–2.2 mm diam., ovate to elliptical in outline, ribs raised or almost flush, whitish, pale yellow to pale yellow-brown, glabrous, style base persistent, *c.* 0.15 mm long, 0.3 mm wide. (Figs 1–4)

Diagnostic characters: Differs from *Lepidosperma concavum* in the finely scabrous and non-viscid culm margins (culm margins of *L. concavum* are puberulous and viscid). Differs from *L. sieberi* in the larger habit (0.6–1.2 *vs* 0.2–0.6 m high), and longer (8–17 *vs* 3–10(–15) cm long) but more-slender inflorescence that is less branched.

Lepidosperma sieberi is generally smaller and notably has culms 3–6 (rarely to 7.5) (*vs* 5.3–7.9) mm wide, spikelets 7.1–9.8 (*vs* 5–8) mm long, fertile floral bracts 6.9–8.3 (*vs* 6–7) mm long and nutlets 1.4–1.9 (*vs* 2.0–2.2) mm wide.

Lepidosperma latens K.L.Wilson is superficially similar, but can readily be distinguished by the fine, harsh scabrous margins that easily cut the skin when attempting to pull out leaves or culms.

Distribution and abundance: Known from three locations in the Sydney region, from Manly (Blue Fish Point, Sydney Harbour National Park), Kamay Botany Bay National Park, on the southern side of Botany Bay, and near Bundeena in the north-eastern part of Royal National Park. Although it is locally common at this latter location, the actual number of individuals (a few hundred to a few thousand) may be low once extensive clonality is accounted for. Populations near Blue Fish Point and in Kamay Botany Bay National Park appear to be relatively small (10–100 individuals).

Habitat: Dense shrubland or heath, often windswept being not far behind the sea-cliffs, dominated by Coast Teatree (*Leptospermum laevigatum*) or mallee eucalypts that provide heavy shade, on pale grey sand over sandstone. The population at Manly appears be in what is classified by Tozer *et al.* (2010) as Sandstone Headland Scrub (their map unit HL p. 127), but the scale of their map is such as not to show small areas of vegetation units. This unit is described as occurring 'on coastal headlands formed by Hawkesbury Sandstone between Bouddi and Otford including Sydney Heads, Cape Banks and Royal National Park. Outlying stands occur further south on Beecroft Peninsula at Jervis Bay.'

The populations at Kurnell and in Royal National Park fall within a mapped mosaic of this unit and Coastal Sandplain Heath (unit HL p. 139 on the map of Tozer *et al.* 2010). The latter is described by them as 'on podsolised sand dunes, usually perched on coastal sandstone plateaux up to 150 m ASL' and has a broadly similar species composition to their HL p. 127. They regard HL p. 139 as restricted to small patches at Kurnell (which are not shown on their map of the region), Jibbon (NE Royal National Park) and Jervis Bay (Beecroft and Booderee).

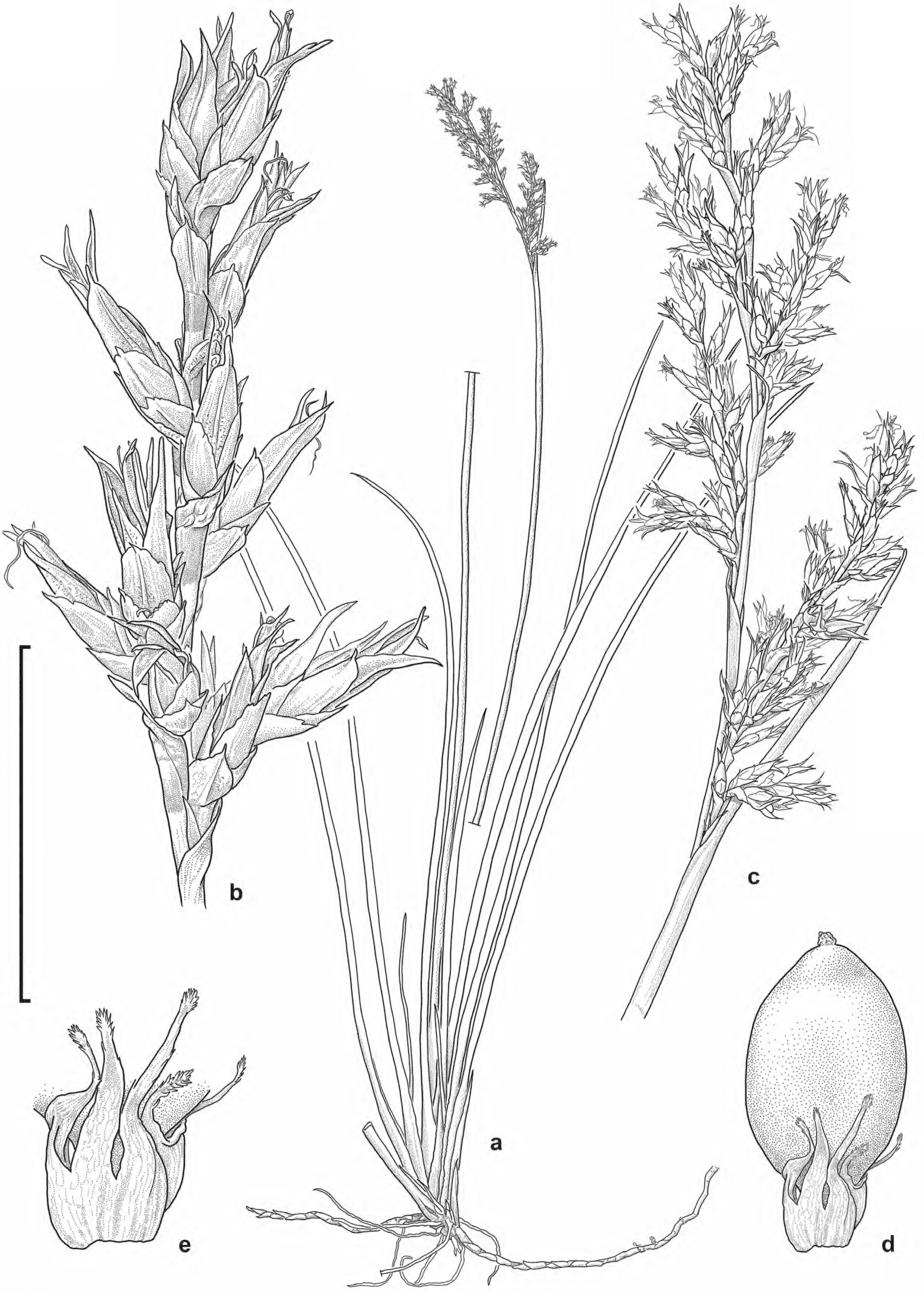

Fig. 1. *Lepidosperma prospectum*, from Jibbon Trail, Royal National Park. A. Plant habit including spreading rhizomes. B. Inflorescence branchlet and spikelets. C. Inflorescence. D. Nutlet with perianth attached. E. Perianth scales with scabrous hairs at apex. Voucher: *R.L. Barrett RLB 9330* (NSW). Illustration by Lesley Elkan. Scale = : a = 20 cm, b = 1.5 cm, c = 5 cm, d = 0.5 cm, e = 0.3 cm.

Fig. 2. *Lepidosperma prospectum*, herbarium specimen from Bundeena Coastal Walk, Royal National Park. Voucher: *G.T. Plunkett 171 & K.L. Wilson* (NSW).

Fig. 3. *Lepidosperma prospectum*, from Jibbon Trail, Royal National Park. A. Habitat with Cronulla in the background. B, C. Plant habit. D. Plant base with rhizomes and sand-binding roots . E. Leaf (left) and culm (right) faces. F. Inflorescence. G. Spikelet with anthers. H. Spikelet with style. I. Fruiting spikelet. Voucher: *R.L. Barrett RLB 9330* (NSW). Photos by R.L. Barrett.

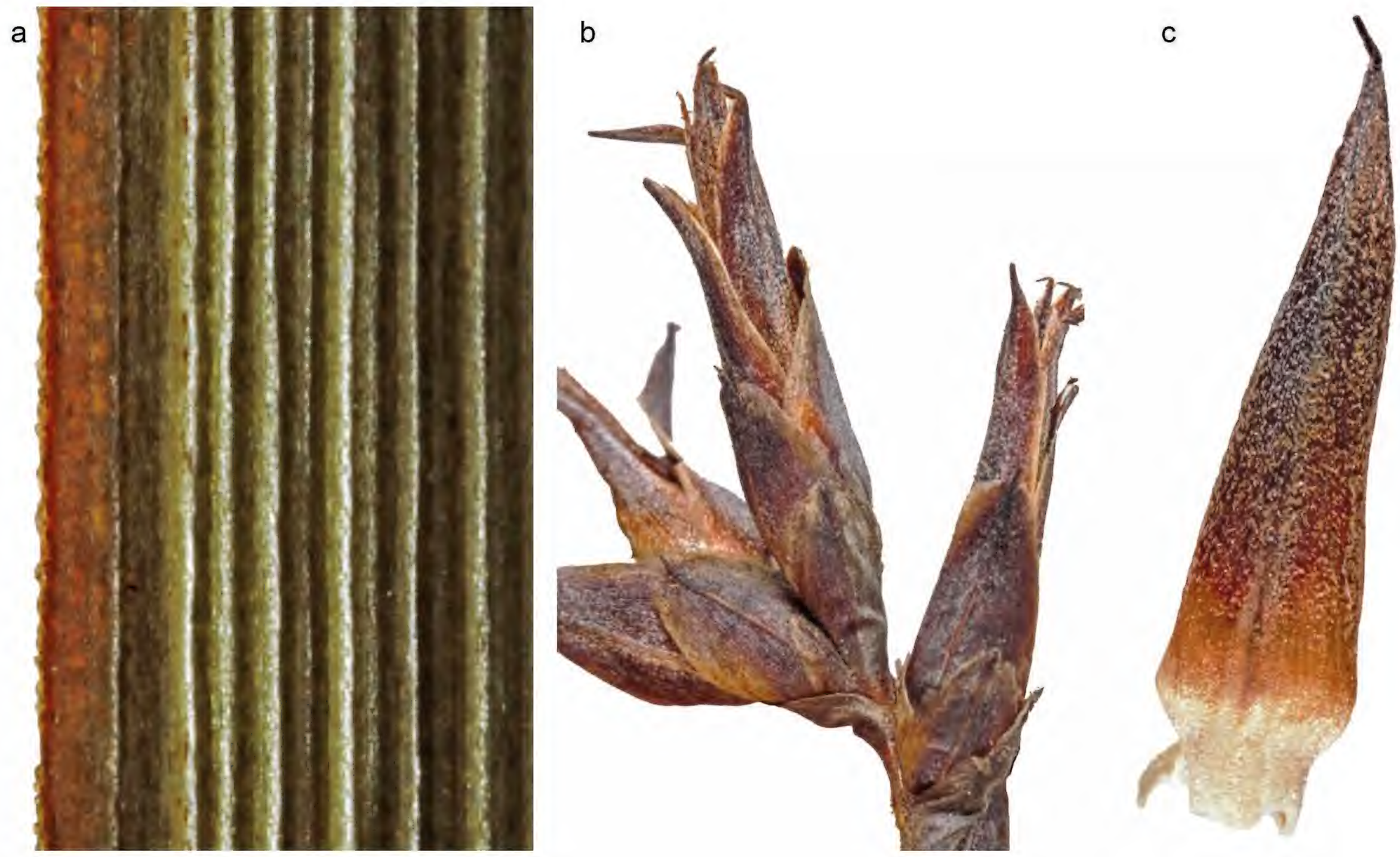

Fig. 4. *Lepidosperma prospectum*, microphotographs. A. Leaf (left) margin. B. Spikelets. C. Fertile glume indumentum. Voucher: *R.L. Barrett RLB 9330* (NSW). Photos by R.L. Barrett.

This species is recorded in association with *Acacia myrtifolia*, *A. suaveolens*, *Allocasuarina distyla*, *Banksia ericifolia*, *B. integrifolia*, *B. serrata*, *Boronia floribunda*, *Bossiaea ensata*, *Caustis pentandra*, *Corymbia gummifera*, *Dampiera stricta*, *Dianella revoluta*., *Dichondra repens*, *Eriostemon australasius*, *Eucalyptus burgessiana*, *E. oblonga*, *Ficinia nodosa*, *Gahnia clarkei*, *Glycine clandestina*, *Gompholobium glabratum*, *Gonocarpus tetragynus*, *Goodenia heterophylla*, *Hakea laevipes*, *H. propinqua*, *Hibbertia scandens*, *Hypolaena fastigiata*, *Isopogon anethifolius*, *Lambertia formosa*, *Lepidosperma concavum sens. strict.*, *L. sieberi*, *Leptospermum laevigatum*, *Leucopogon microphyllus*, *Lomandra glauca*, *L. longifolia*, *Melaleuca armillaris*, *M. nodosa*, *Mirbelia rubiifolia*, *Oxylobium cordifolium*, *Patersonia glabrata*, *Phebalium squamulosum* subsp. *argenteum*, *Pultenaea stipularis*, *Schoenus brevifolius, S. ericetorum, S. pachylepis* and *Westringia fruticosa*.

Phenology: Flowers recorded for September–October. Fruit probably maturing November–December.

Specimens examined: NEW SOUTH WALES: SW corner of pollution control facility near fence, *c*. 700 m SW of Blue Fish Point, Manly, Sydney, 78 m alt., 28 Jan. 2009, *R.L. Barrett & K.L. Wilson RLB 5554* (NE, NSW, PERTH); Royal National Park, *c*. 100 m SE along Coast Walk Track from Beachcomber Ave, Bundeena, 12 Sept. 2013, *G.T. Plunkett 171 & K.L. Wilson* (NE, NSW); Royal National Park, *c*. 0.5 km SE of Bundeena on sea-front track to Marley, 25 Jan. 1992, *K.L. Wilson 7975* (NSW).

Conservation: *Lepidosperma prospectum* is currently known from three small populations. Due to the severe impacts of urbanisation on coastal vegetation in the Sydney Basin (Benson and Howell 1990; Keith 1994; Fairley 2004; Bear 2010), it is highly likely that some populations of this species have been destroyed. Fortunately, it is protected in Kamay Botany Bay National Park, Royal National Park and Sydney Harbour National Park, where the surrounding vegetation is largely intact. Based on available information and observations, *Lepidosperma prospectum* is classified as Vulnerable (VU B2a+C2a) according to IUCN (2012) criteria.

Given the threat status, searching for additional populations in suitable habitat in the Sydney Basin should be prioritised. Recent fieldwork in similar coastal environments farther south (around Jervis Bay and Cape Dromedary) has not found any other populations. Based on the presence of similar vegetation types on coastal sandstone plateaux, further surveys are recommended around Bouddi Peninsula (described by McRae 1990 and Bell 2004), on Middle Head in Sydney Harbour, along the coast south of Bundeena in Royal National Park, and around Jervis Bay (all described by Tozer *et al.* 2010) is warranted.

Etymology: The epithet is from the Latin verb *prospicio, -ere, -exi, prospectum* (to look into the distance, have a view), in reference to the coastal and somewhat elevated habitat of this species behind the sea-cliffs. It is from such vantage points that the *Gamaragal*, *Gweagal* and *Dharawal* people would have observed the first Europeans arriving by boat some 250 years ago. The epithet is chosen to acknowledge the deep historical and living indigenous knowledge of the Australian environments gained through careful observation. In contrast,

the recent recognition of this species highlights a gap in the documented European knowledge of the Sydney region since Joseph Banks and Daniel Solander first collected plants (but not this species) around Botany Bay 250 years ago.

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The family Calymperaceae (Bryophyta) in Australia. Part 4: The genus *Calymperes*

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Abstract

Fifteen species of the moss genus *Calymperes* Sw. ex F.Weber are known from Australia. Each species is described and illustrated in detail, and a key to species and distribution maps are provided.

Introduction

Calymperes Sw. ex F.Weber is the type genus of family Calymperaceae, and comprises about 50 species (Tropicos 2021). Reese and Stone (2012) reported 14 species from Australia, and an additional species, *Calymperes boulayi,* has since been added to the country's flora. In the following treatment the descriptions are based on studies of a representative sample of collections held in Australian herbaria, supplemented by our own collections.

The notation !d indicates that a high-resolution digital image of a specimen has been seen via JSTOR Global Plants (www.plants.jstor.org).

Intramarginal cells (also known as teniolae or intramarginal ribs) characterise the genus *Calymperes* and are significant in differentiating between species (see the glossary in Seppelt *et al.* 2021).

CALYMPERES Sw. ex F.Weber, *Tab. Calyptr. Operc.* [3] (1814).

Type species: *Calymperes lonchophyllum* Schwägr., designated by Williams (1920).

Plants small to medium sized, to about 10–15(–30) mm tall, forming ± erect tufts, simple or forked; rhizoids usually brown (reddish to dark purple in a few species). Leaves oblong to lanceolate or linear, often dimorphic, commonly with abundant fusiform, seriate-multicellular gemmae on modified tips of gemmiferous leaves; gemmiferous leaves often strongly differentiated from non-gemmiferous leaves and almost always present; leaves bordered entirely or in part by elongate, hyaline cells (border may be weak, incomplete, or ± lacking in

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some leaves in some species); with or without intramarginal rows of differentiated, elongate, mostly hyaline cells; such intramarginal cells sometimes indistinct or lacking in some leaves in some specimens; leaf base composed mainly of a pair of lattices of much larger thin-walled, rectangular hyaline cells (hyaline lamina) usually sharply differentiated from chlorophyllose lamina cells; cells of upper lamina ± isodiametric or ± transversely elongate, at least in part. Gemmae clavate-fusiform, usually abundant, borne on short proboscis-like extensions of leaf tips or, in some species, distinct gemma receptacles. Sporophytes frequent in some species, rare in others; seta relatively short, rarely less than 2 mm, smooth; capsule erect, exserted (or emergent in a few species), cylindrical; calyptra large and persistent, spirally furrowed when dry, twisted round the seta below the capsule, enclosing and clasping the capsule by its rostrate operculum, opening by vertical slit-like fissures at maturity; peristome lacking.

Etymology: Greek *kalymma* (hood, veil) + *peres* (going beyond), referring to the large calyptra, completely covering the capsule.

Distribution: All Australian records of *Calymperes* are from the tropics or subtropics. Species are generally epiphytic, but occasionally grow on soil or rocks.

Notes: The key in Seppelt *et al.* (2021) can be used to separate *Calymperes* from other genera of Calymperaceae.

The following key to species of *Calymperes* known from Australia differs from that provided by Reese and Stone (2012). The first couplet of their key is based on the leaves being narrowly linear and lamina cells of the leaf limb being ± transversely elongate (*C. lonchophyllum, C. serratum*) or leaf shape various but not narrowly linear and chlorophyllose lamina cells ± isodiametric (remaining taxa). While the leaves of *C. lonchophyllum* and *C. serratum* are indeed linear-elongate, the chlorophyllose lamina cells in the specimens examined are not markedly transversely elongate but ± isodiametric. Reese and Stone (2012) also differentiated these two species on the length of the medial cells of the abundant axillary hairs, a difference also noted by Ellis (2020).

Within *Calymperes* many species show considerable variation in specific characters, and identification can often be difficult. Key features may be present or sometimes absent in a species, and some may show marked differences in habit whether wet or dry. Habitat and substrate type should be noted for collection and identification. Leaves hold important identification features: monomorphic or dimorphic (particularly the shape of gemmiferous leaves versus non-gemmiferous stem leaves); leaf margins (with rows of intramarginal cells, with or without a stereome, bordered or not, with or without a unistratose extension into the sheathing base); cell surface (smooth or ornamented); structure of the costa in section; proportional length of the hyaline lamina and shape of its distal delineation, as well as cell size; gemmae and where they arise; and the presence or absence of gemma receptacles at the leaf apex, and their shape. Because of the extent of variation shown in some species, several shoots may need to be examined to arrive at a good species identification.

Reese (1993) noted that sterile specimens of *Calymperes* that lack differentiated intramarginal cells (termed 'teniolae' in earlier publications) may be difficult to distinguish from *Syrrhopodon* species.

Gemmae are common within the Calymperaceae and in *Calymperes* species are mostly produced on modified gemmiferous leaves. Gemmae are generally clavate-fusiform, uniseriate (rarely branching), and commonly smooth (Ellis and Pressel 2020). Gemmae production is generally finite; after gemmae are shed, gemmiferous leaves no longer participate in asexual reproduction. However, within Australia, two *Calymperes* species – *C. lonchophyllum* and *C. serratum* – produce gemmae continuously on multicellular stalk-like structures, termed gemmipars by Reese (2001), after earlier descriptions by Hughes (1971). Reese (2001) described gemmae so produced as typically ridged, papillose, and red-brown in colour.

Key to the species of *Calymperes* in Australia

1 Leaves length 10–20' width 2

1: Leaf length 4–8' width (except gemmiferous leaves up to 10' as long) 3

2 Cells of hyaline lamina usually sharply distinct from adjacent cells of limb; costa usually with a single row of medial guide cells; cells of axillary hairs often > 5 times as long as wide ..... **C. lonchophyllum**

2: Cells of hyaline lamina not sharply distinct from adjacent cells of limb; costa usually with 2 rows of medial guide cells, occasionally with additional subsidiary guide cells; cells of axillary hairs mostly < 3 times as long as wide ..... **C. serratum** var. **serratum**

3 Leaves lacking rows of differentiated intramarginal cells, cells of the lamina above and outside the hyaline cells all chlorophyllose 4

3: Leaves with rows of differentiated intramarginal cells, the rows sometimes weak, obscure, ± hidden by papillae, or may be ± lacking in some leaves 7

4 Gemmiferous leaves distinctly differentiated from non-gemmiferous leaves, abruptly flared at apex to form a receptacle enclosing the gemmiferous tip of costa ..... **C. boulayi**

4: Gemmiferous leaves differentiated or not, with a proboscid or rounded apex, lacking a flared receptacle 5

5 Leaves almost uniform, oblong to lanceolate, lingulate; gemmae arising all around leaf tip ..... **C. tenerum**

5: Leaves uniform, or dimorphic with gemmiferous leaves longer than non-gemmiferous leaves, variously shaped; gemmae only on adaxial surface of leaf tip 6

6 Leaves not or slightly dimorphic; margins unistratose, entire; cells of limb smooth to bluntly papillose, weakly to moderately convex on adaxially ..... **C. motleyi**

6: Leaves usually strongly dimorphic; margins uni- to multi-stratose, usually irregularly notched to denticulate, occasionally entire; cells of limb smooth to unipapillose abaxially, bulging mammillose adaxially ..... **C. graeffeanum**

7 Leaf margins grossly tuberculate; intramarginal cells obscured by tuberculose margins, ± distinct in sheath and base of limb; distal margins of hyaline lamina scalariform ..... **C. strictifolium**

7: Leaf margins entire or variously toothed or roughened, not tuberculate; intramarginal rows of cells distinct or sometimes weakly developed, or lacking in some leaves; distal margins of hyaline lamina scalariform or rounded 8

8 Leaves strongly dimorphic; gemmiferous leaves stiffly erect, consisting mostly of a narrowly winged costa, lacking saucer-shaped gemma receptacle at apex 9

8: Leaves mostly monomorphic or only slightly dimorphic; gemmiferous leaves mostly differentiated only at tips, or narrowed throughout but clearly laminate and similar to non-gemmiferous leaves (if strongly differentiated throughout, then gemmiferous leaves flexuose, not stiffly erect, bearing gemmae only on adaxial surface at apex; saucer-shaped gemma receptacle present or absent 12

9 Margins of non-gemmiferous leaves coarsely toothed above and distal margins of hyaline lamina ending in a ± horizontal line ..... **C. porrectum**

9: Margins of non-gemmiferous leaves entire or only inconspicuously toothed and distal margins of hyaline lamina ending in an arched or angled line 10

10 Distal margins of hyaline lamina rounded distally; leaves strongly dimorphic ..... **C. couguiense**

10: Distal margins of hyaline lamina scalariform; leaves dimorphic or not 11

11 Leaf margins weakly dentate or entire; intramarginal rows of cells distinct in non-gemmiferous leaves, marginal or almost so, in the shoulders 1(–3) cells intramarginal ..... **C. subintegrum**

11: Leaf margins usually irregularly notched or denticulate, sometimes entire; intramarginal cell rows lacking above the hyaline region but may be present in leaf base ..... **C. graeffeanum**

12 Adaxial distal cells of hyaline lamina distinctly mammillose, the mammillae pointing towards leaf tip; gemmae borne all round excurrent costa ..... **C. erosum**

12: Adaxial distal cells of hyaline lamina smooth; gemmae borne only on adaxial surface of leaf tip 13

13 Gemmae borne in distinct receptacles 14

13: Gemmae not borne in distinct receptacles 15

14 Leaves crispate when dry; tips of gemmiferous leaves typically strongly folded downward onto adaxial leaf surface when dry; 1–2 intramarginal cell rows, 1 cell inside margin, intermittent, hardly reaching beyond shoulder ..... **C. crassinerve**

14: Leaves variously contorted but never crispate when dry; tips of gemmiferous leaves not folded downward onto adaxial leaf surface; 2–4 intramarginal cell rows, 1–3 cell rows inside margin, extending into limb but often inconspicuous there ..... **C. moluccense**

15 Plants robust, 1–2.5 cm high, dark green to blackish green; leaves linear with ± parallel sides in limb from a slightly broader base; distal margin of hyaline lamina irregular, often with files of hyalocysts extending upwards into the chlorophyllose cells of limb ..... **C. taitense**

15: Plants small, to 1 cm high, yellowish green to brownish green; leaves oblong-lanceolate from a broad erect-sheathing base; distal margin of hyaline lamina ± smooth, at a broad to narrow angle to costa, hyalocysts not extending upwards into the chlorophyllose cells of limb..... **C. afzelii**

1. *Calymperes afzelii* Sw., *Jahrb. Gewächsk* 1: 3 (1818)

Original material: 'Hab. ad Sierram Leonam Africes inque America calidiori. Arboreus.'

Type: Sierra Leone, *s.loc.*, 1792–1796, *A.Afzelius s.n.* holotype: ?S not seen; isotypes: E00011440!d, BM000855290, NY01113882!d.

Illustrations: Eddy (1990: 115), Reese and Lin (1991: 335), Ellis and Tan (1999: 6), Reese (2007: 659).

Plants to 10 mm tall, yellowish green to brownish green, gregarious or in thin to dense tufts or turfs. Stems erect, simple or forked; rhizoids reddish to yellowish brown. Leaves ± dimorphic, patent when moist, slightly curved or contorted when dry; lingulate from an erect-sheathing base, 3–6 mm long. Non-gemmiferous leaves with acute apex, costa ending in or just below apex; gemmiferous leaves with margins constricted at tips, forming a distinct proboscis-like apex with narrowly revolute margins, costa extending into proboscis; limb usually plane, margins thickened but lacking internal stereome, entire or serrate, especially above. Cells of limb small, 4–5 μm, almost smooth to finely papillose abaxially, bulging-papillose adaxially; intramarginal cells mostly distinct and conspicuous in lower limb and sheathing base. Costa smooth in sheath, in upper limb with epidermal layer of conical-mammillose cells, ± rounded in section, with 4–5(–6) medial guide cells, adaxial and abaxial stereid bands. Hyalina lamina sharply defined, reaching to just above shoulder level, ending above in a broad to narrow angle at the costa, with scalariform margins. Gemmae common, adaxial on tips of gemmiferous leaves. Sporophytes not seen in Australian material. (Fig. 1)

Diagnostic characters: *Calymperes afzelii* is perhaps more distinctive under the microscope than in the field, being of similar size to several other species. The ligulate leaves with intramarginal rows of cells, leaf margins that are almost entire or very finely denticulate by projecting cell ends, and the proboscid leaf apex are useful features for identification. *Calymperes erosum* is superficially similar but differs in having the distal cells of the hyaline lamina adaxially mammillose and gemmae borne all around the tip of the excurrent costa which does not have the marginal lamina incorporated into the proboscis. *Calymperes taitense* is a larger, darker plant with the distal margins of the hyaline lamina interlocking with the chlorophyllose lamina cells above, and there are rather coarse marginal teeth.

Distribution: In Australia, known from tropical Western Australia to the Northern Territory (Melville Island) and north-eastern Queensland, from inland of Mackay to Cape York (Fig. 16.1). Otherwise a pantropical species, widespread from southern USA to northern South America, tropical and subtropical central Africa, Madagascar, Réunion, Seychelles, India, Malesia, the Philippines, Papua New Guinea and Vanuatu.

Habitat: Grows on bark, logs and occasionally on rock, in low-altitude forests to about 800 m altitude.

Selected specimen seen: Queensland: Hinchinbrook: Broadwater Camping Area, Abergowrie State Forest, near Ingham, 5 Sep 2013, *D.A.Meagher & A.Cairns WT-220* (BRI AQ1016952).

Etymology: After Swedish botanist Adam Afzelius (1750–1837), who collected the type in Sierra Leone.

Typification: The holotype should be in the Swartz herbarium at the Swedish Museum of Natural History (S), but it is not listed in the museum's collections database and we have been unable to determine whether it is extant. The isotype in E is from herb. Menzies and is annotated 'Calymperes afzelii' on the original sheet. The original packet is annotated 'Sierra Leone leg. Afzelius'. The specimen was determined as *Calymperes perottii* Besch. by Hugh Dixon in 1936, but redetermined as *C. afzelii* by Sean Edwards in 1974. The isotype in BM was determined as such by Len Ellis in 1993 and is from herb. Hampe. It is annotated 'ex herb. Weberi *Calymperes afzelii* Sw. Sierra Leone leg. Afzelius'. The isotype in NY is annotated '*Calymperes afzelii* Sw. Ad Sierra Leone, Africa Afzelius' and was annotated as type material by Peter Florschütz in 1959. Although a note attached in 1986 by Bill Reese says that it does not agree with *C. afzelii* sensu Edwards (1980), we have no reason to think it is not type material.

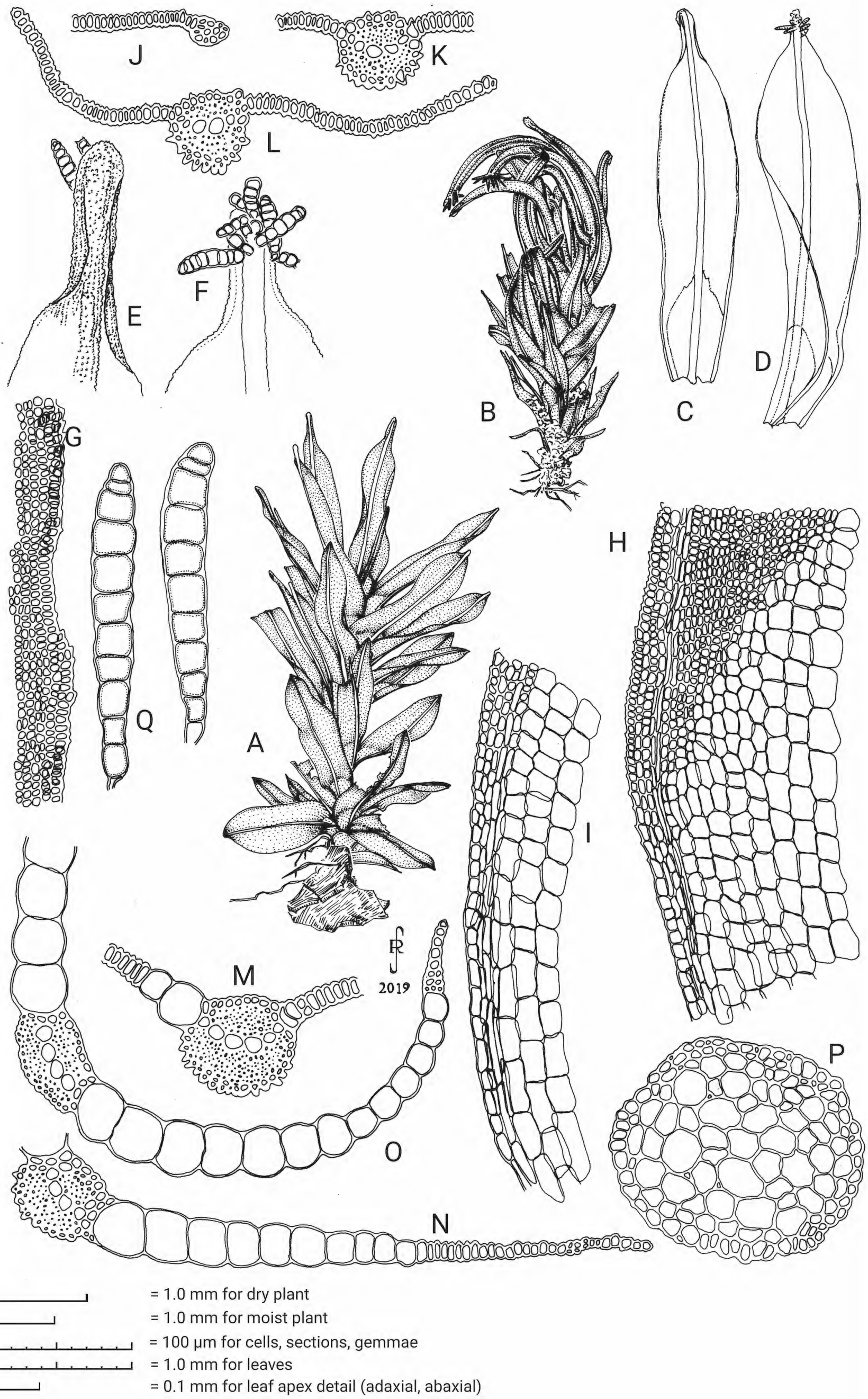

Fig. 1. *Calymperes afzelii* Sw. **A:** Habit of plant, showing both gemmiferous and non-gemmiferous leaves, drawn moist. **B:** Habit of plant, drawn dry. **C, D:** Gemmiferous leaves. **E, F:** Gemmiferous leaf apex (E – abaxial, F – adaxial view). **G:** Mid to upper lamina marginal cells. **H:** Cells of shoulder region of leaf with intramarginal cells, chlorophyllose lamina, and hyaline lamina. **I:** Cells of basal margin of leaf showing intramarginal cells and cells of the hyaline lamina. **J:** Cells of mid-leaf margin. **K, L:** Costa and leaf sections of mid-limb of leaf. **M:** Section of costa and adjacent cells at distal margin of hyaline lamina. **N, O:** Sections of leaf base through hyaline lamina, chlorophyllose lamina, and intramarginal row 2–3 cells thick. **P:** Stem section. **Q:** Gemmae. Drawn from: *D.A.Meagher & A.Cairns WT-220.*

2. *Calymperes boulayi* Besch., *Ann. Sci. Nat., Bot., sér. 8*, 1: 268, 278 (1896)

Original material: 'Bornéo leg. Korthals, Hb. Boulay; Hb. Mus. Par. sub C. Palisoti Dzy et Molk.); Java, associé à C. platycinclis Nob. in Hb. Mus. Lugd. Batav. sub C. moluccensi).'

Type: Indonesia, Kalimantan (Borneo), 1831–1836, *P.Korthals s.n.* lectotype: BM000851724!d, designated by Ellis (1988); isolectotypes: ?L (not seen), NY2045381!d, PC0148228!d.

Illustrations: Eddy (1990: 245), Ellis and Tan (1999: 8).

Plants mostly small, 3–5(–10) mm tall, forming low, compact tufts, green to yellowish green. Leaves soft-textured, dimorphic in gemmiferous plants; non-gemmiferous stem leaves recurved-patent from a slightly broadened sheathing base, lingulate to spathulate, chlorophyllose lamina flat or with incurved margins, 2–3 mm long, 0.5–0.6 mm wide, margins weakly crenulate-denticulate at shoulders; apex broadly rounded; intramarginal rows of cells lacking, upper leaf margins not bordered; cells of chlorophyllose lamina thin-walled, quadrate, 5–7 μm wide, 8–10 μm wide near hyaline lamina. Gemmiferous leaves longer than non-gemmiferous leaves, rigid, erect-spreading when moist, incurved when dry, 3–5 mm long, the blade narrowing from the shoulders or at least in upper limb, acuminate, abruptly flared at apex to form a receptacle enclosing the gemmiferous tip of costa. Costa in non-gemmiferous stem leaves ending just below leaf tip; in section with a median row of guide cells but lacking adaxial or abaxial stereids, cells adjacent to guide cells about 1/2 diameter of guide cells, thin-walled, epidermal layer of cells conical-mammillose, subepidermal cells on abaxial side narrower than interior cells, sometimes in the form of substereids. Distal margins of hyaline lamina broadly rounded above, sharply delimited, ending at or slightly above shoulders, upper hyalocysts ± strongly inflated; intramarginal cell rows weakly developed, indistinct. Sporophytes common. Seta short, about 2–3 mm long; capsule exserted; calyptra densely scabrid with ± erect spinous cell ends. (Fig. 2)

Diagnostic characters: The flared, saucer-shaped gemma receptacles of *Calymperes boulayi*, which are readily apparent under a hand lens even when the leaves are dry, are similar to those of *C. moluccense*, but the latter species clearly has leaves with intramarginal rows of cells extending into the limb. *C. graeffeanum* also has flared gemma receptacles but these are narrower and do not form a saucer-shaped gemma receptacle as in *C. boulayi*. Ellis (1999) nominates the somewhat inflated appearance of the costa and absence of stereids therein in both gemmiferous and non-gemmiferous leaves, the absence of intramarginal rows of cells in the upper leaf, and the distinctive 'collared' gemma receptacle as distinguishing characteristics of *C. boulayi*. However, we are unable to comment further as only one specimen was available for examination.

Distribution: In Australia known from a single collection near Cairns, Queensland (Fig. 16.2). Elsewhere, widespread throughout tropical Asia from Sri Lanka to Thailand, Malesia, Papua New Guinea, Solomon Islands, Micronesia, and Polynesia. Only one Australian collection is known: *I.G.Stone 15349*, collected 27 July 1979 at Crystal Cascades and identified by Len Ellis. Because that collection was not available for study, a specimen from Papua New Guinea is illustrated here.

Habitat: Epiphytic on tree trunks and branches. The habitat of the only known Australian specimen is unknown; the specimen from Papua New Guinea cited below was growing on the trunk of a mature coconut palm in a garden.

Selected specimen seen: Papua New Guinea: Morobe Province; S.I.L. Guesthouse, Lae, 11 Jan 1981, *H.Streimann 10750* (CANB 8102712).

Etymology: After French botanist Jean-Nicolas Boulay (1837–1905), from whose herbarium one of the syntypes was obtained.

Typification: The isolectotype in PC is ex herb. Mus. Ludg. Batav. and is annotated '= *C. boulayi Calymperes Palisoti* Schw. non *C. fasciculatum* Dozy *C. moluccense*' in handwriting and 'Borneo Korthals legit.' in print. It was not cited by Menzel and Schultze-Motel (1990) nor Ellis and Tan (1999).

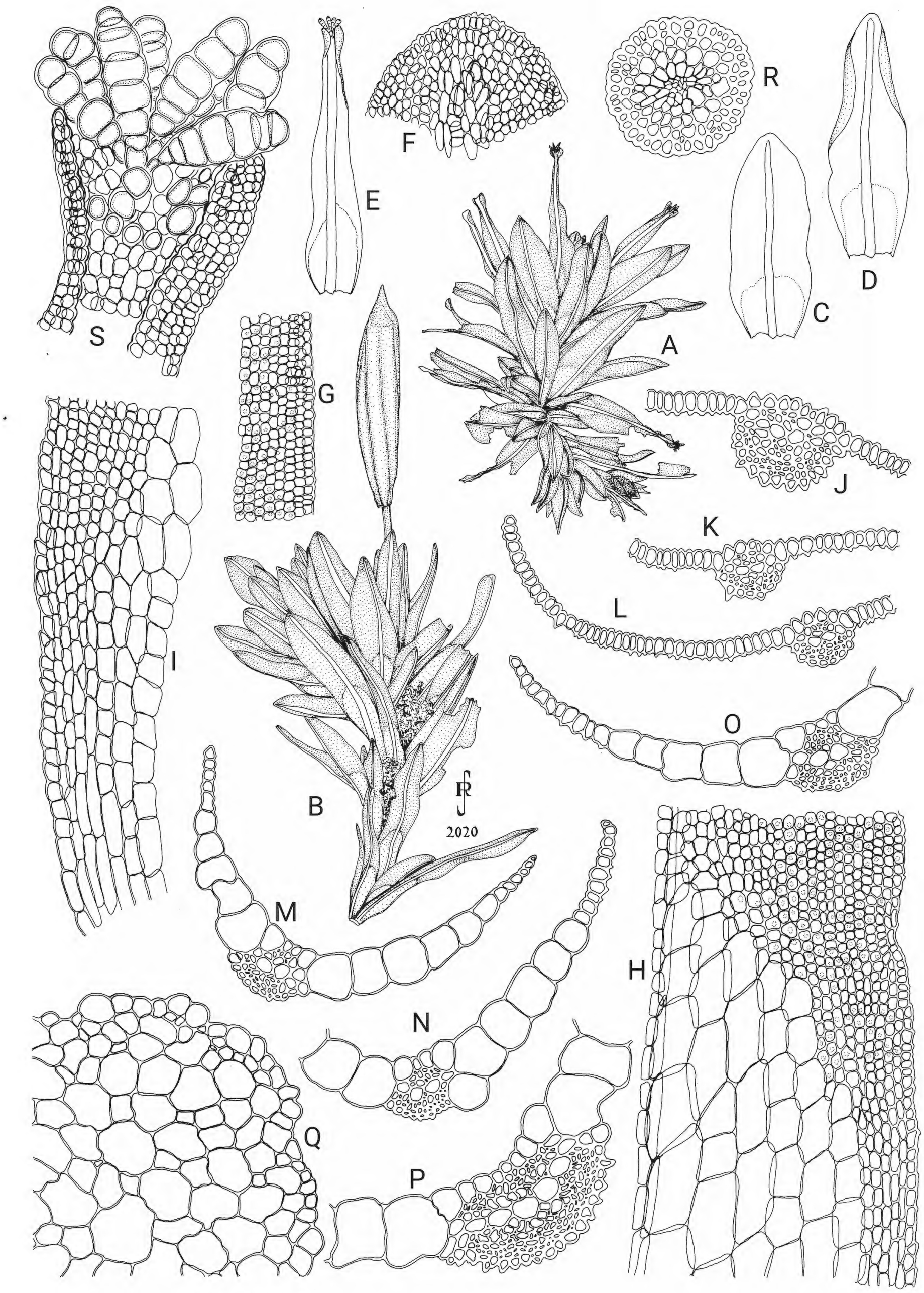

Fig. 2. *Calymperes boulayi* Besch. **A:** Plant with gemmae and perigonia, drawn moist. **B:** Plant with capsule, drawn moist. **C, D:** Stem leaves. **E:** Leaf with gemmae. **F:** Cells of apex of non-gemmiferous stem leaf. **G:** Marginal cells of leaf limb, abaxial view. **H:** Hyaline lamina, abaxial view. **I:** Cell of basal margin of leaf. **J–L:** Sections of leaf limb. **M–P:** Sections of leaf sheath. **Q:** Part stem section. **R:** Section of seta. **S:** Detail of gemma receptacle with gemmae. Drawn from: *H.Streimann 10750.*

3. *Calymperes couguiense* Besch., *Ann. Sci. Nat., Bot., sér. 5*, 18: 206 (1873)

Original material: 'Ad cortices in monte Cougui (Balansa)'.

Type: New Caledonia, Grande Terre, Mt Koghi (Cougui), 1868–1870, *M.Balansa s.n.* PC0148258!d, PC0148259!d.

Illustrations: Ellis (2002: 154).

Plants dull, dark green to brownish, to 5(–8) mm tall, in loose tufts and turfs. Stems erect, simple; rhizoids brown. Leaves strongly dimorphic; non-gemmiferous stem leaves oblong-lanceolate from a broader base, (2.2–)2.5–4.0 mm long, straight when moist, ± involute or folded along limb; when dry, loosely curled and involute; margins slightly thickened, ± entire; cells of chlorophyllose lamina ± isodiametric, sharply papillose with large papillae on both surfaces; intramarginal cell rows present but often obscured by inrolled margins; gemmiferous leaves roughened, stiffly erect when wet, erect to curved when dry, the chlorophyllose lamina reduced to narrow wings or ridges in upper 1/3 of leaf. Distal margins of hyaline lamina rounded to almost scalariform. Gemmae common, borne terminally at the leaf apex, surrounded by an apical fringe of smaller sterile, finger-like projections. Sporophytes unknown. (Fig. 3)

Diagnostic characters: Reese and Stone (2012) suggested that *C. couguiense*, *C. strictifolium* and *C. subintegrum* form a natural group, based on their general similarity. Colonies of *C. couguiense* and *C. subintegrum* often appear bristly because of the stiffly erect gemmiferous leaves. In *C. subintegrum* the distal margins of the hyaline lamina are acute, and in *C. strictifolium* the leaf margins are grossly tuberculate. In addition, both of those species lack the fringe of sterile projections at the apex of gemmiferous leaves that are present in *C. couguiense*.

Distribution: Occurs in north-eastern Queensland from Paluma Range, north of Townsville, to Torres Strait (Fig. 16.3). Elsewhere known from eastern Papua New Guinea (New Britain), New Caledonia, and Pacific islands as far east as Tahiti.

Habitat: Wet to very wet lowlands and foothills from sea level to about 500 m, growing on tree bark and sometimes soil or rock, in coastal mesophyll and notophyll vine forests.

Selected specimens seen: Australia, Queensland: c. 8 km west of Babinda, 7 July 1987, *W.D. Reese 17038*, *I.G. Stone* & *A.G. Stone* (CANB 2103890A). Solomon Islands: Choiseul, Sasamuga, Vavudu village, 3 Aug 1991, *M. Qusa s.n.* (CBG 9300171.1).

Etymology: Cougui + *–ense* (coming from), referring to Mt Cougui in New Caledonia, where the type was collected.

Typification: PC0148258 and PC0148259 are on the same sheet, which bear an original label from Herb. Mus. Paris that identifies the material as type. The former is annotated '*Syrrhopodon* [amended to *Calymperes* in pencil] Besch. a Mont. Cougui.' in handwriting and 'Nouvelle Calédonie. M. Balansa, 1868–1870.' in print, and the latter is annotated '*C. Couguiense* Besch. Cougui Balansa' in handwriting. Neither is identified as having come from herb. Bescherelle, but it is clear that both are original material, the latter probably being a segregate of the former. BM-000675199 is from Bescherelle's herbarium but is annotated in script 'Nv-Caled. Balade Vieillard No. 1776'. It was identified as type material by Bill Reese in 1982 (perhaps thinking 'Balade', a locality on Grande Terre, was 'Balansa'), but Len Ellis noted that it was not type material in an annotation dated July 2000. A 2001 annotation from Len Ellis identifies this specimen as a neotype, but as there are at least two extant specimens of the original material a neotye is not required. A lectotype should be chosen from the material in PC, but a close inspection of the two specimens is needed before this is done.

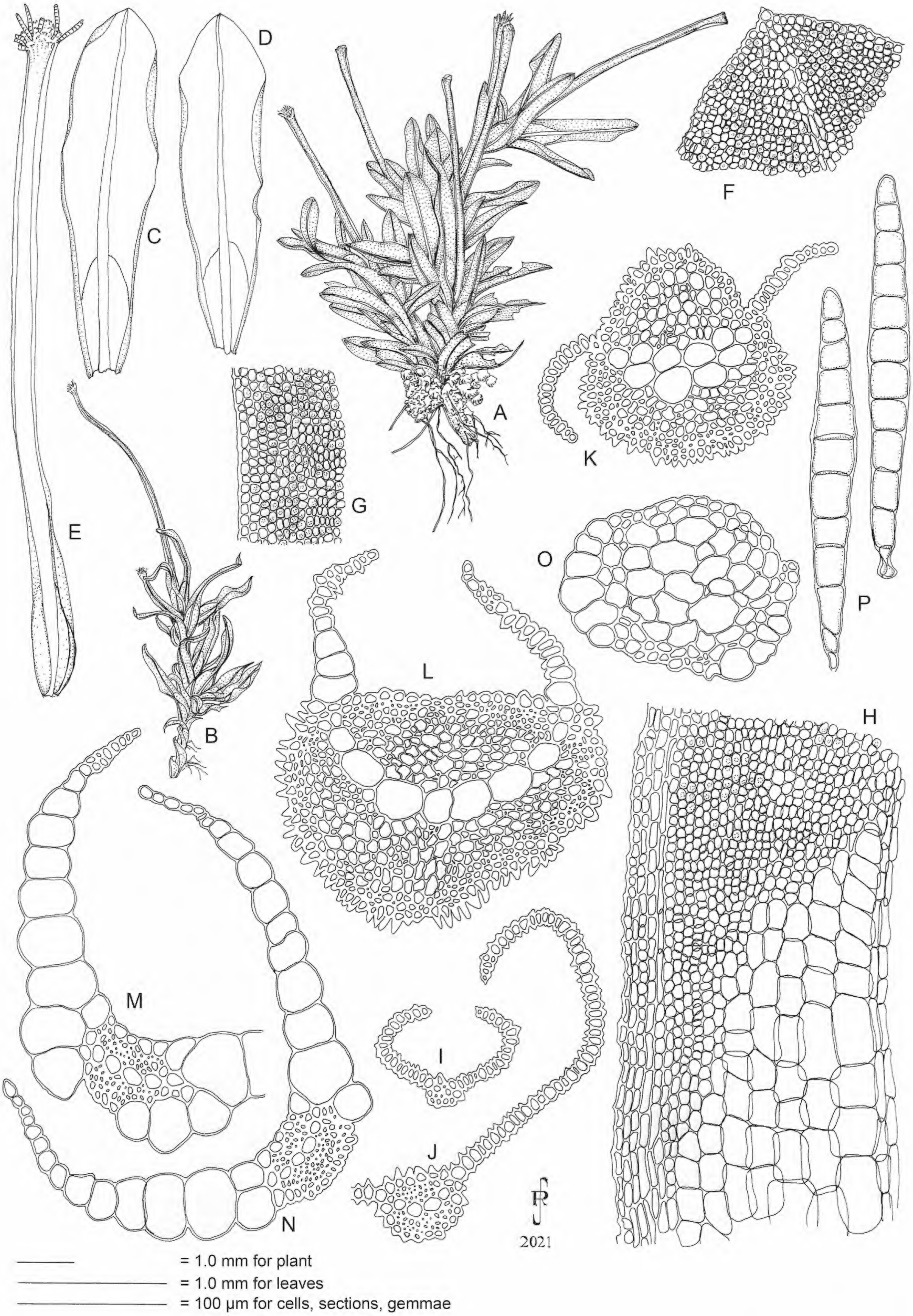

Fig. 3. *Calymperes couguiense* Besch. **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C, D:** Vegetative leaves. **E:** Gemmiferous leaf. **G:** Cells of upper leaf margin. **H:** Cells of leaf shoulder region, with hyaline lamina, intramarginal cells, cells of chlorophyllose lamina. **I:** Section near apex of gemmiferous leaf. **J:** Section of mid to upper region of gemmiferous leaf. **K, L:** Mid-leaf sections of gemmiferous leaf. **M, N:** Sections of chlorophyllose lamina of gemmiferous leaves. **O:** Stem section. **P:** Gemmae. Drawn from *M. Qusa 122*.

4. *Calymperes crassinerve* (Mitt.) A.Jaeger, *Ber. Thätigk. St. Gallischen Naturwiss. Ges.* 1871–72: 481 (1873). *Thyridium crassineve* Mitt., *J. Linn. Soc., Bot.* 10: 189 (1868)

Original material: 'Tutuila, on bark. No. 129.'

Type: Samoa, Tutuila, *T. Powell 129,* 1845–1867, holotype NY1127898!d; isotypes BM000663116!d, BM000663119!d

Illustration: Eddy (1990: 122).

Plants small, to about 5 mm tall, green to yellowish green, forming low dense tufts. Stems erect to repent, mostly simple. Leaves dimorphic; non-gemmiferous stem leaves 1–2 mm long, blunt, crisped when dry; folded to weakly undulate when moist; lingulate above a broader base, shoulders often flaring; margins unistratose, entire; intramarginal rows distinct, 1–2 cells wide and 1 cell inside margin, intermittent, not extending far up limb above shoulders; hyaline lamina truncate distally, ending in a ± horizontal line at about leaf shoulder level, sharply demarked from chlorophyllose cells of lamina, the lamina cells not decurrent down costa or margins; gemmiferous leaves slightly longer than non-gemmiferous leaves, contracted below apical saucer-shaped gemma receptacle, typically strongly inflexed near apex when dry so that gemmiferous portion becomes appressed to adaxial leaf surface; gemmae pale green, in hairbrush-like tufts adaxially on leaf tips. Costa strong, especially in gemmiferous leaves, failing below leaf tip; in section with well-developed stereid bands above and below guide cells and a differentiated epidermal layer. Cells of chlorophyllose lamina ± rounded-quadrate, thin-walled, ± smooth, typically biconvex. Sporophytes rare in Australian collections. Seta reddish, 1.5–2.0 mm long; capsules emergent, 1.0–1.5 mm long; calyptra about 2.5 mm; operculum about 0.75 mm long; spores 34–36 μm in diameter, finely granular. (Fig. 4)

Diagnostic characters: This small moss is easily recognised by its small lingulate leaves (1–2 mm long) and when dry by its ± crispate leaves and gemmiferous leaf tips which fold downwards and inwards to the adaxial surface of the leaf, giving the appearance of a brush-like tuft of gemmae. *Calymperes crassinerve* is generally smaller and more compact than *C. boulayi* or *C. moluccense*, although the form of the gemmiferous leaves is similar. When dry, the gemmiferous leaf tips of *C. moluccense* and *C. boulayi* remain erect. *Calymperes crassinerve* differs from *C. boulayi* in having distinct rows of intramarginal cells bordering the proximal chlorophyllose lamina. *Calymperes motleyi* is also similar in the tips of the gemmiferous leaves curving inwards when dry but lacks intramarginal cells, as in *C. boulayi*, but the cells of the chlorophyllose lamina of *C. motleyi* are thick-walled and the hyaline lamina broader. The widely flared shoulders and flat distal margins of the hyaline lamina of *C. crassinerve* also resemble *Mitthyridium* but there the leaf border is always broader and located at the margin, not intramarginal.

Distribution: Known in Queensland from Cardwell to Cape York (Fig. 16.4). Elsewhere widespread from tropical Asia to New Guinea and eastward into Oceania.

Habitat: Occurs on trees, including mangroves, stumps, rotted logs, rarely on rock, mostly at or near sea level but up to about 500 m altitude.

Selected specimens seen: Queensland: Cook: Emmagen Creek crossing, Cape Tribulation Road, Daintree National Park, 11 May 2013, *D.A.Meagher & A.Cairns WT-160* (BRI AQ1016908); Cairns: Behana Gorge, Behana Creek, south of Gordonvale, 16 May 2014, *D.A.Meagher & A.Cairns WT-454* (BRI AQ1019055); Cassowary Coast: Clift Road via Elderbeck, 2.5 km north of Cardwell, 26 May 2015, *D.A.Meagher & A.Cairns WT-601A* (BRI AQ1019799).

Etymology: Latin *crassus* (thick) + *nervum* (sinew), referring to the thick costa.

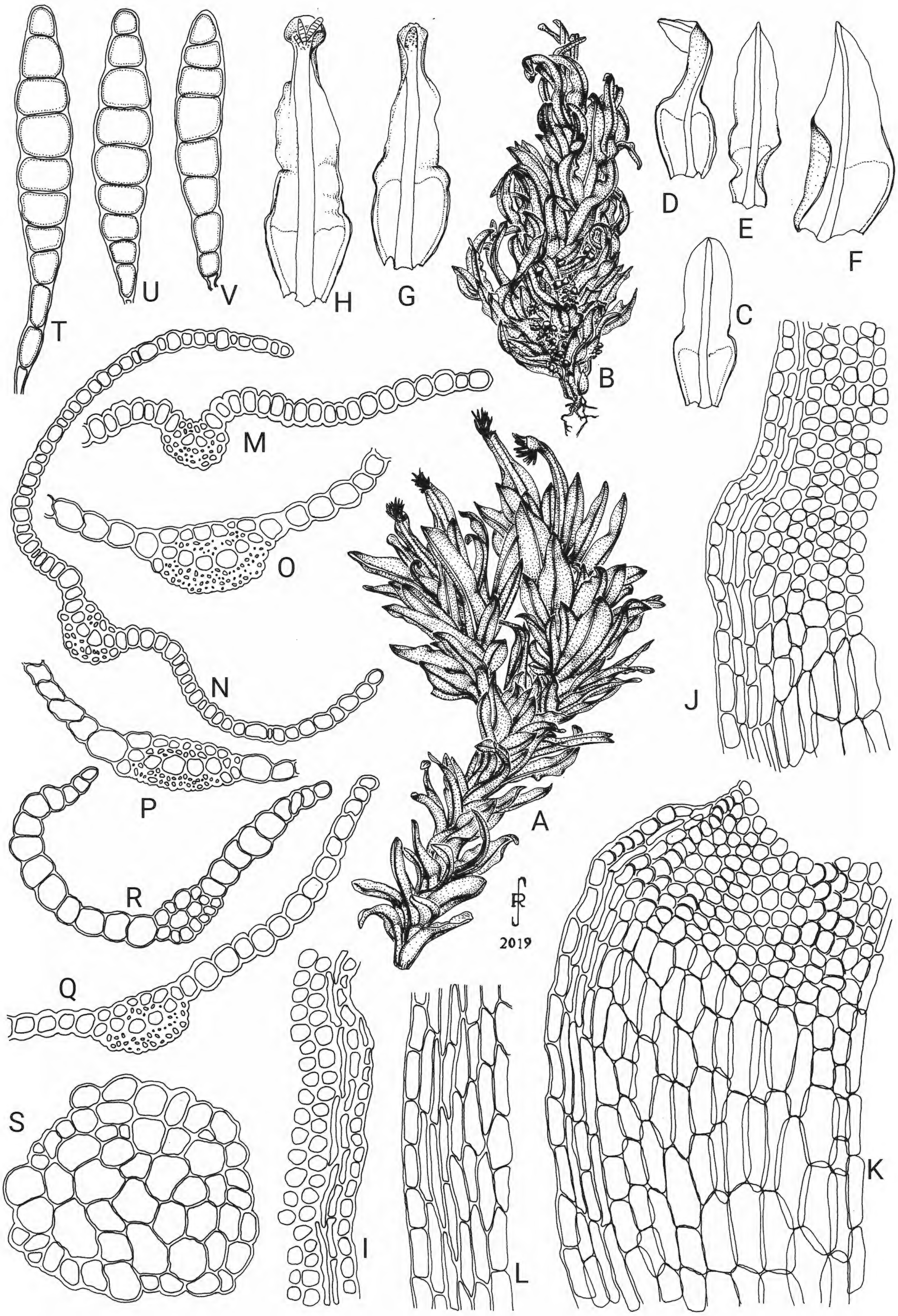

Fig. 4. *Calymperes crassinerve* (Mitt.) A.Jaeger **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C–F:** Non-gemmiferous leaves. **G, H:** Gemmiferous leaves. **I:** Cells of mid to lower margin at mid limb. **J:** Cells of shoulder region with hyaline lamina, chlorophyllose lamina cells and intramarginal cells. **K:** Cells of shoulder region. **L:** Cells of basal angle of leaf. **M, N:** Sections of leaf limb. **O–R:** Sections of sheathing base of leaf. **S:** Stem section. **T–V:** Gemmae. Drawn from: *D.A.Meagher & A.Cairns WT-601A*.

5. *Calymperes erosum* Müll.Hal., *Linnaea* 21: 182 (1848).

Original material: 'An Baumstämmen bei Paramáribo. Unter No. 539, des Hb. Kegelian, zwischen Cladonien steril. Mit Früchten erhalten von Herrn Professor Miquel unter *Hypnum microtheca* n. sp.'

Type: Suriname: near Paramaribo, July 1844, *H.Kegel 539*, lectotype: PC0148269!d, designated by Reese (1961); isolectotypes: GOET011748!d, JE04001397!d, ?BM000575254!d, ?BM000855301.

Illustrations: Eddy (1990: 117), Reese and Lin (1991: 334), Ellis and Tan (1999: 8).

Plants small to medium sized, to 10 mm tall, green to yellowish green or dark green, sometimes with a pinkish tinge, forming low dense tufts or turfs. Stems erect, often curved, simple or forked; rhizoids reddish brown. Leaves somewhat dimorphic, mostly 3–4 mm long, about 1.0 mm wide at shoulders; ascending to spreading when moist, lanceolate to ligulate above a broader base; margins slightly thickened, finely serrate; when dry leaves incurved and with involute margins; leaf apex very variable, obtuse to bluntly mucronate with the costa percurrent in non-gemmiferous stem leaves and excurrent in gemmiferous leaves with gemmae borne all round the tip. Cells of chlorophyllose limb small, ± quadrate, 5–8 μm wide, minutely papillose abaxially, bulging conical-mammillose adaxially; intramarginal cell rows usually well developed, forming a pellucid band 3–6 cells intramarginal at shoulders, with 1–2 rows of ± quadrate marginal cells externally, continuing well up margins of limb, extending into the base and intramarginal by 1–2 rows of pellucid thin-walled cells. Hyaline lamina sharply delimited from chlorophyllose lamina, the distal margins broadly rounded, ending at or just above shoulder; upper cells of hyaline lamina and lower chlorocysts with conspicuously projecting cell ends, at least abaxially, giving a scabrid appearance to leaf surface. Gemmae common, reddish, borne all round tip of costa in spherical clusters. Sporophytes not seen in Australian collections. (Fig. 5)

Diagnostic characters: *Calymperes erosum* is similar to *C. afzelii* but differs in that the unistratose, elongate, hyaline intramarginal cells of the leaf sheath of the latter species are bordered on its outside by 3–6 rows of pellucid rectangular cells, not a single row as in *C. erosum*. Gemmae are borne only adaxially in *C. afzelii,* not all round the apex of the costa and the tip of the costa in *C. erosum* is naked and scabrid, whereas in *C. afzelii* the costa apex is bordered by a narrow band of chlorophyllose laminal cells. Further, the upper cells of the hyaline lamina in *C. afzelii* are not highly inflated or mammillate as in *C. erosum*. When dry the leaf sheath of *C. erosum* usually has a characteristic glossy iridescence.

Distribution: In Australia, known from northern Northern Territory and north-eastern Queensland from Cape York to inland of Mackay (Fig. 16.5). Reese and Stone (2012) reported *Calymperes erosum* from the Kimberley region in Western Australia, but the collection they cited (*I.G.Stone 23497*) is a mixture of five species, none of which is *C. erosum*. A pantropical species.

Habitat: Occurs on trees, including mangroves, roots, rock, soil, humus, in monsoonal rainforest from sea level to about 1000 m altitude.

Selected specimen seen: Queensland: Cassowary Coast: Edmund Kennedy National Park, 23 July 1987, *W.D.Reese, I.G.Stone and A.Stone 17203* (BRI AQ1019727).

Etymology: Latin *erosum* (eroded), referring to the erose-denticulate margins of the leaves.

Typification: The material collected by Miquel was identified by Reese (1961) as belonging to *Calymperes uleanum* Broth., a long-recognised synonym of *C. pallidum* Mitt. Ellis (2018) discussed the confusion surrounding the supposed holotype of *Calymperes erosum* in GOET suggested by Reese (1993), and pointed out that the lectotypification of *C. erosum* by Reese (1961) remains effective under the International Code (Turland *et al.* 2018). The isolectotype in JE and two likely isolectotypes in BM cited here have not been recognised previously.

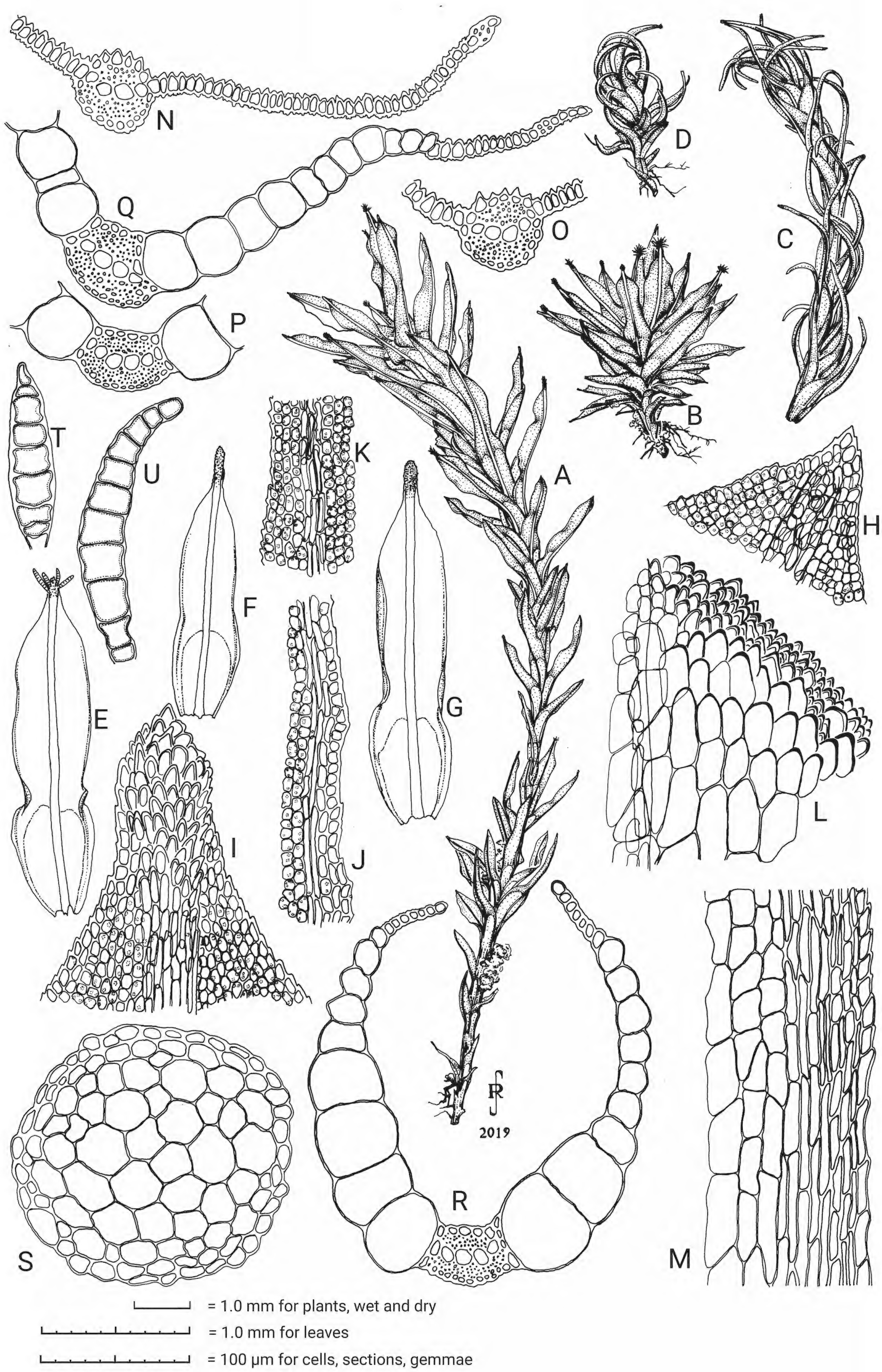

Fig. 5. *Calymperes erosum* Müll.Hal. **A, B:** Habit of plants, drawn moist. **C, D:** Habit of plants, drawn dry. **E–G:** Gemmiferous leaves. **H:** Cells of apex of non-gemmiferous leaf. **I:** Cells of apex of gemmiferous leaf. **J:** Cells of lower limb margin, with intramarginal cells. **K:** Marginal cells of upper limb, showing intramarginal hyaline cells. **L:** Mammillose cells of upper hyaline lamina and lower chlorophyllose laminal cells. **M:** Marginal cells of sheathing leaf base. **N, O:** Sections of costa and chlorophyllose lamina of upper leaf. **P–R:** Sections of costa and sheathing leaf base. **S:** Stem section. **T, U:** Gemmae. Drawn from: *W.D.Reese, I.G.Stone and A.Stone 17203.*

6. *Calymperes graeffeanum* Müll.Hal., *J. Mus. Goddefroy* 3(6): 64 (1874)

Original material: 'Upolu, as truncos Mangrove dictos.'

Type: Samoa: Upolu, *s.d.*, *Graeffe, s.n.* holotype: B (destroyed); isotypes: BM000855010!d, BM000855011!d, BM000518500!d, NY01113939!d.

Illustrations: Eddy (1990: 127), Ellis and Tan (1999: 9).

Plants small, often wiry, to about 5 mm tall; pale green to darker green, forming loose to compact tufts. Stems mostly simple, erect or curved; rhizoids brown to reddish brown. Leaves usually strongly dimorphic: non-gemmiferous leaves mostly 2–3 mm long, mostly involute or folded when moist, oblong to linear from a broadened base; margins uni- to multi-stratose, sometimes with stereids, notched to minutely irregularly denticulate or rarely ± entire, occasionally toothed at shoulders; cells of chlorophyllose lamina smooth to unipapillose abaxially, bulging mammillose adaxially; narrow rows of intramarginal cells present but confined to the leaf base, rarely reaching the leaf shoulders, sometimes indistinct; hyaline lamina broad, distinct, scalariform to rounded distally; cells of chlorophyllose lamina decurrent down margins of hyaline lamina, becoming ± hyaline, smooth and rectangular towards the base; gemmiferous leaves usually narrow and erect, the gemma receptacle often well-developed and spoon-shaped, occasionally reduced or lacking and forming only an indistinct receptacle, not completely enclosing the gemmiferous apex of the costa although chlorophyllose lamina usually continuous as a narrow band forming a rounded or truncate leaf tip. Gemmae common, glossy, red to reddish green. Sporophytes not seen in Australian collections. (Fig. 6)

Diagnostic characters: *Calymperes graeffeanum* is similar to *C. boulayi*, but the gemma receptacles of the former are narrower and the upper leaf margin is usually bordered and at least bistratose. *Calymperes motleyi* and *C. tenerum* are also similar to *C. graeffeanum*, particularly in the absence of gemmiferous leaves, but they lack differentiated intramarginal cells in the leaf base. The distal margins of the hyaline lamina in *C. graeffeanum* are broader and rounder to scalariform distally, rather than truncate as in *C. motleyi* and *C. tenerum*. The leaf shoulders are often ± toothed in *C. graeffeanum*.

Distribution: In Australia known from Northern Territory and east Queensland from Cape York as far south as near Proserpine (Fig. 16.6). Elsewhere widespread from Cameroon (Western Central Africa), the Seychelles, India, Sri Lanka, tropical Asia, Malesia, the Philippines, Papua New Guinea, Micronesia and Polynesia. Grows on tree trunks, logs and boulders in complex mesophyll vine forests, and on mangrove trunks; mostly at or near sea level, but up to about 500 m altitude.

Note: The leaf shoulder is often indistinct in Australian material of *C. graeffeanum* we have seen, and the apex of gemmiferous leaves has a broader laminal area. However, without further investigation we prefer to maintain this species in the Australian flora.

Selected specimens seen: Queensland: Whitsunday: Hayward Gully, Conway National Park, 1 Jul 2014, *A.J.Franks AJF1407002* (BRI AQ0910162); Cassowary Coast: Boulder Creek, north of Mt Tyson, west of Alligator's Nest, near Tully, 18 Nov 2014, *D.A.Meagher and A. Cairns WT-462* (BRI AQ1019058).

Etymology: After Swiss naturalist Eduard Heinrich Graeffe (1833–1916), who collected the type.

Typification: According to annotations on BM000518500 and BM000855010, the type was collected from the trunk of a mangrove, as stated in the protologue. The holotype was undoubtedly destroyed in 1943 when the Berlin herbarium was hit by a bomb. As far as we know, a lectotype has not been selected.

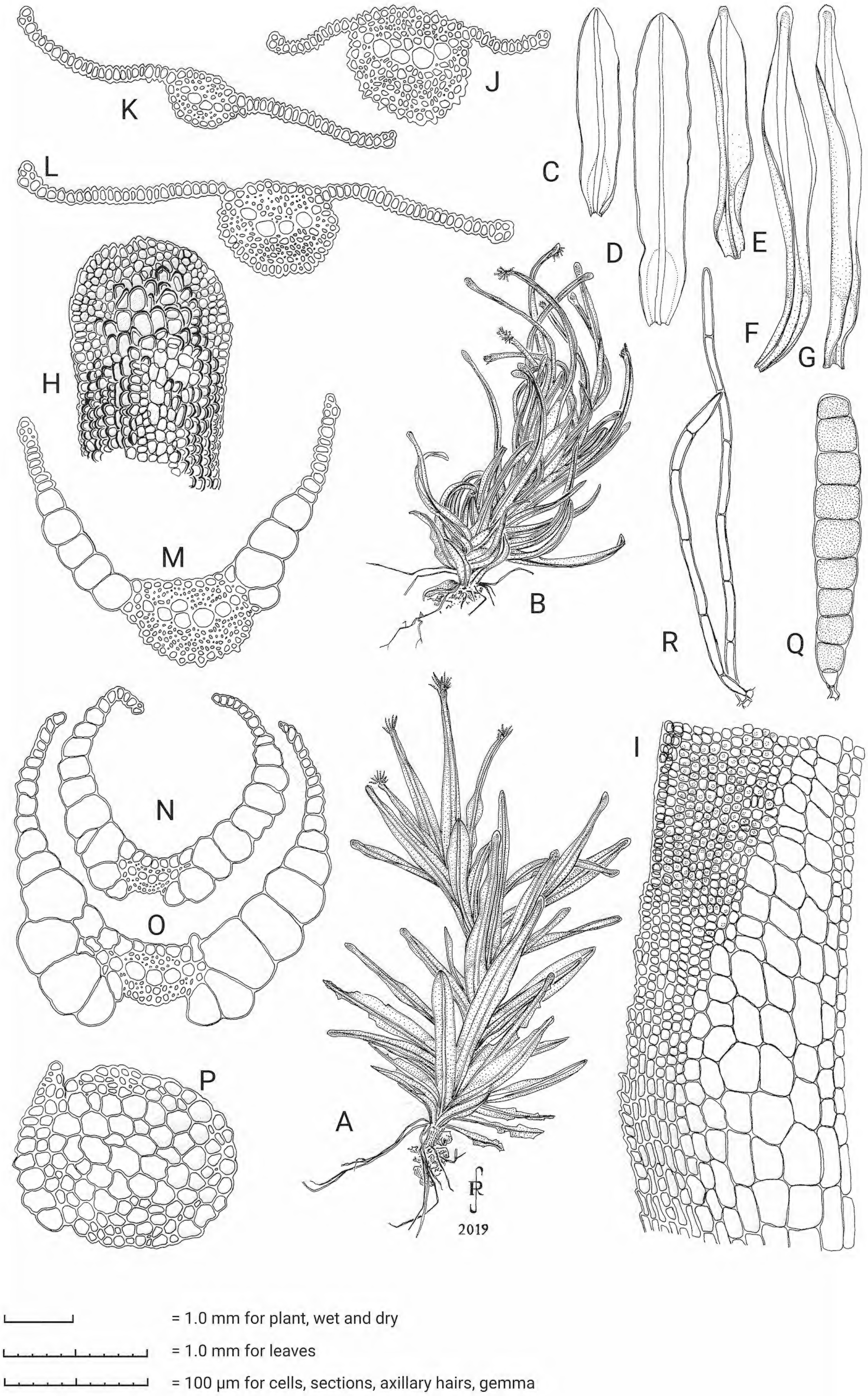

Fig. 6. *Calymperes graeffeanum* Müll.Hal. **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C, D:** Non-gemmiferous leaves. **E–G:** Gemmiferous leaves. **H:** Cells of leaf apex, abaxial view. **I:** Cells of leaf shoulder region. **J:** Section of gemmiferous leaf near apex. **K, L:** Sections of chlorophyllose lamina and costa. **M–O:** Sections of sheathing leaf base and costa. **P:** Stem section. **Q:** Gemma. **R:** Axillary hairs. Drawn from: *A.J.Franks AJF1407002*.

7. *Calymperes lonchophyllum* Schwägr., *Sp. Musc. Frond., Suppl.* 1, 2: 333 (1816)

Original material: 'In arboribus Gujanae legit clar. Richard.'

Type: French Guiana, 1781–1789, *L.C.Richard s.n.* lectotype: G00042891 not seen, designated by Ellis (2011); isolectotypes: E00226214!d, PC0148308!d.

Illustrations: Eddy (1990: 97), Reese and Lin (1991: 327), Akiyama and Reese (1992: 204), Ellis and Tan (1999: 11).

Plants light to dark green, forming low tangled mats; ± stemless; rhizoids light brown. Leaves monomorphic, ribbon-like from an ovate sheathing base, 8–25 mm long, sometimes more, limb 0.3–0.5 mm wide, sheathing base about 1.5 mm wide, straight when moist; margins of limb thickened, mostly variously double-toothed above; margins of sheath entire, or serrate from 1 or more marginal rows of delicate protruding hyaline cells; cells of limb transversely elongate, smooth, often irregularly bistratose; intramarginal cells lacking; hyaline lamina large, occupying most of the sheath, sharply delimited distally from chlorophyllose lamina cells which are decurrent down costa and margins, rounded to ± scalariform distally; costa strong, smooth, percurrent, in limb covered by an epidermal layer of cells similar to lamina cells, in section plane adaxially, keeled or strongly convex abaxially, with 1(–2) series of guide cells; intramarginal cells, at least in lower part of sheath, 2–4 cells wide, bordered on outside by 1–2 rows of thin-walled hyaline ± denticulate cells. Gemmae reddish, sparse, inconspicuous, ± warty, borne adaxially on leaf tips, occasionally forming on abaxial and adaxial gemmipars along costa and margins of older leaves. Sporophytes not seen in Australian material. (Fig. 7)

Diagnostic characters: The linear leaves with transversely elongate lamina cells should readily distinguish *Calymperes lonchophyllum* from all other Australian species except *C. serratum*. In *C. serratum*, the distal cells of the hyaline lamina gradually blend with the adjacent chlorophyllose cells of the limb, in contrast to the sharply demarcated hyaline lamina of *C. lonchophyllum*. The medial and distal cells of the axillary hairs are also much shorter in *C. serratum* than those of *C. lonchophyllium*. Rhizoids of *C. serratum* are dark red-purple while those of *C. lonchophyllum* are brown.

Distribution: In Australia, known from north-eastern Queensland, from Iron Range to Cardwell (Fig. 16.7). A widespread pantropical species known from the Caribbean, Central America, northern South America, Andaman Islands, India, Sri Lanka, Thailand, China, Malesia, the Philippines, Papua New Guinea, east to Polynesia and Fiji.

Habitat: Grows on tree trunks and rock, mainly along streams, to about 600 m altitude.

Selected specimen seen: Queensland: Cassowary Coast: Along 'Sullivan's Track', about 6 km WNW of Cardwell, 22 July 1987, *W.D.Reese, I.G.Stone and A.Stone 17179* (BRI AQ1019726).

Etymology: Greek *lonche* (spearhead) + *phyllon* (leaf), referring to the shape of the leaves.

Typification: E00226214, not cited by Ellis (2011), is undoubtedly an isotype as it is annotated 'Cayennes (a cl. Richard)' and its appearance agrees with that of the other isotype. (Cayenne is the capital of French Guiana.)

Fig. 7. *Calymperes lonchophyllum* Schwägr. **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C:** Leaf. **D, E:** Cells of leaf apex. **F, G:** Cells of leaf shoulder region. **H, I:** Sections of chlorophyllose lamina and costa. **J, K:** Cells of sheathing leaf base. **L:** Stem section. **M:** Leaf base with hyaline lamina. **N:** Leaf apex with gemmae. **O:** Gemma. **P:** Leaf base with paraphysis-like axillary hairs. **Q:** Axillary hairs. Drawn from: *W.D.Reese, I.G.Stone and A.Stone 17179.*

8. *Calymperes molucccense* Schwägr., *Spec. Musc. Frond., Suppl. 2*, 1(2): 99. pl. 127 (1824)

Original material: 'In insula Rauwack Moluccensi lignis adnatum legit clar. Gaudichaud iu itinere cum navarcho Freycinet instituto.'

Type: Indonesia, Muluku Islands, Rauwack Island, 1823, *C.Gaudichaud-Beaupré s.n.* lectotype: G00042890, not seen, designated by Ellis (2011); ?isolectotypes: BM000518167!d, BM000851801!d, BM000851798!d, BM000851786!d, M000851791!d.

Illustrations: Eddy (1990: 123), Reese and Lin (1991: 339), Ellis and Tan (1999: 12).

Plants 5–15 mm tall, in dark green to reddish brown tufts; shoots densely foliate. Stems erect or curved, simple or forked; rhizoids brown to reddish brown. Leaves wide-spreading from the sheathing base when moist; non-gemmiferous stem leaves oblong-lingulate from a broader base, shoulders often flaring, to 3.5 mm long; gemmiferous leaves to 4.0 mm long, with a narrowing limb ± obsolete in the acumen then abruptly flaring to form a receptacle around the gemmiferous tip of costa. Leaf margins slightly thickened above, entire to weakly denticulate; cells of limb thick-walled with rounded lumens, smooth to distinctly papillose abaxially, bulging to sharply mammillose-papillose adaxially; intramarginal cell rows distinct and pellucid at leaf shoulders, 2–4 cells wide and 1–3 cells intralaminal, continuing into limb but becoming ill-defined, reduced to a 1–2 stratose marginal or 1 cell intralaminal band of yellowish, slightly elongated cells which may run into the leaf acumen or end well below the apex. Distal margins of the hyaline lamina rounded or truncate distally, ending level with or just below the leaf shoulder level in an abrupt and almost transverse line. Gemmae glossy, reddish to dark red or blackish, often in hairbrush-like tufts adaxially at tips of gemmiferous leaves. Sporophytes rarely found in Australia. Calyptra about 3.5 mm long. Seta yellow to red, 2–3 mm long. Capsule about 2 mm long; operculum about 0.75 mm long. Spores 24–40 μm in diameter, surface finely granular. (Fig. 8)

Diagnostic characters: The stiff texture and dark colour of *Calymperes moluccense* are distinctive, as are the gemmiferous leaves with the gemmae occurring in hairbrush-like tufts and usually borne in a distinct receptacle. A common and often abundant species at low altitudes, particularly along the coast. Plants of *C. graeffeanum* and *C. motleyi* can look very similar, but in those species the intramarginal cells are confined to the leaf base. *Calymperes crassinerve* is also similar, but there the leaves are crispate and the gemmiferous leaves have the brush-like tufts of gemmae folded down to the adaxial leaf surface when dry. In *C. moluccense* the gemmiferous leaf tips remain erect when dry, not downfolded at the tips.

Calymperes moluccense also appears to be closely related to *C. palisotii* Schwägr., (not been reported from Australia), and Schwägrichen (1824) himself suggested that it might be a variety of that species. Reese and Mohammed (1985) and Reese *et al.* (1986) treated *C. moluccense* as a synonym of *C. palisotii*, but Ellis (1987) showed that the two species are consistently different and represent separate taxa, the latter species having proboscid, not broadly hooded, gemmiferous leaf apices, and the lamina cells are thinner-walled with rounded mammillae, not sharply conical-mammillate as in *C. moluccense*. *Calymperes palisotii* also lacks the band of thick-walled cells bordering the inner cells of the hyaline lamina, and the intramarginal cells are often discontinuous in the shoulder and lower limb (Ellis 1987, Eddy 1990).

Distribution: Occurs in Australia from Goode Island and Cape York south to Proserpine with a single record from the Northern Territory (Fig. 16.8). Elsewhere known from Andaman Islands, Sri Lanka, south east Asia, China (Hainan Island), Malesia and Oceania.

Habitat: Grows on trees and rocks, in mangrove swamps, from sea level to about 600 m altitude.

Selected specimens seen: Queensland: Cairns: Cape Tribulation National Park, Dubuji Boardwalk, Myall Creek, 12 May 2013, *D.A.Meagher & A.Cairns WT-182* (BRI AQ1016930); Cassowary Coast: Attie Creek Falls, Cardwell Forest Drive, north west of Cardwell, 1 Sept 2013, *D.A.Meagher & A.Cairns WT-224* (BRI AQ1016954).

Etymology: After the Muluku (Molucca) islands, where the type was collected.

Typification: Ellis (2011) noted the confusion about possible isolectotypes and syntypes, and therefore listed only potential isolectotypes cited above and some possible syntypes in G and BM. He did not cite G00050657!d, from Hb. Delessert, which was collected by Gauidichaud on Rawauck and is labelled as type of *Calymperes moluccense*. It was annotated as lectotype of *C. moluccense* by Zen Iwatsuki in 1967 (although he did not publish it as such) but subsequently identified as *C. palisotii* by Bill Reese in 1984. Several other possible isolectotypes or syntypes were not cited by Ellis (2011) (G00050658!d, BM000675192!d, BM000851785!d, BM000851786!d, PC0148327!d, PC0148323!d, PC0148324!d, PC0148325!d, NY01113971!d, MO5912319!d, MO407685!d) but it is beyond the scope of this paper to assess their status.

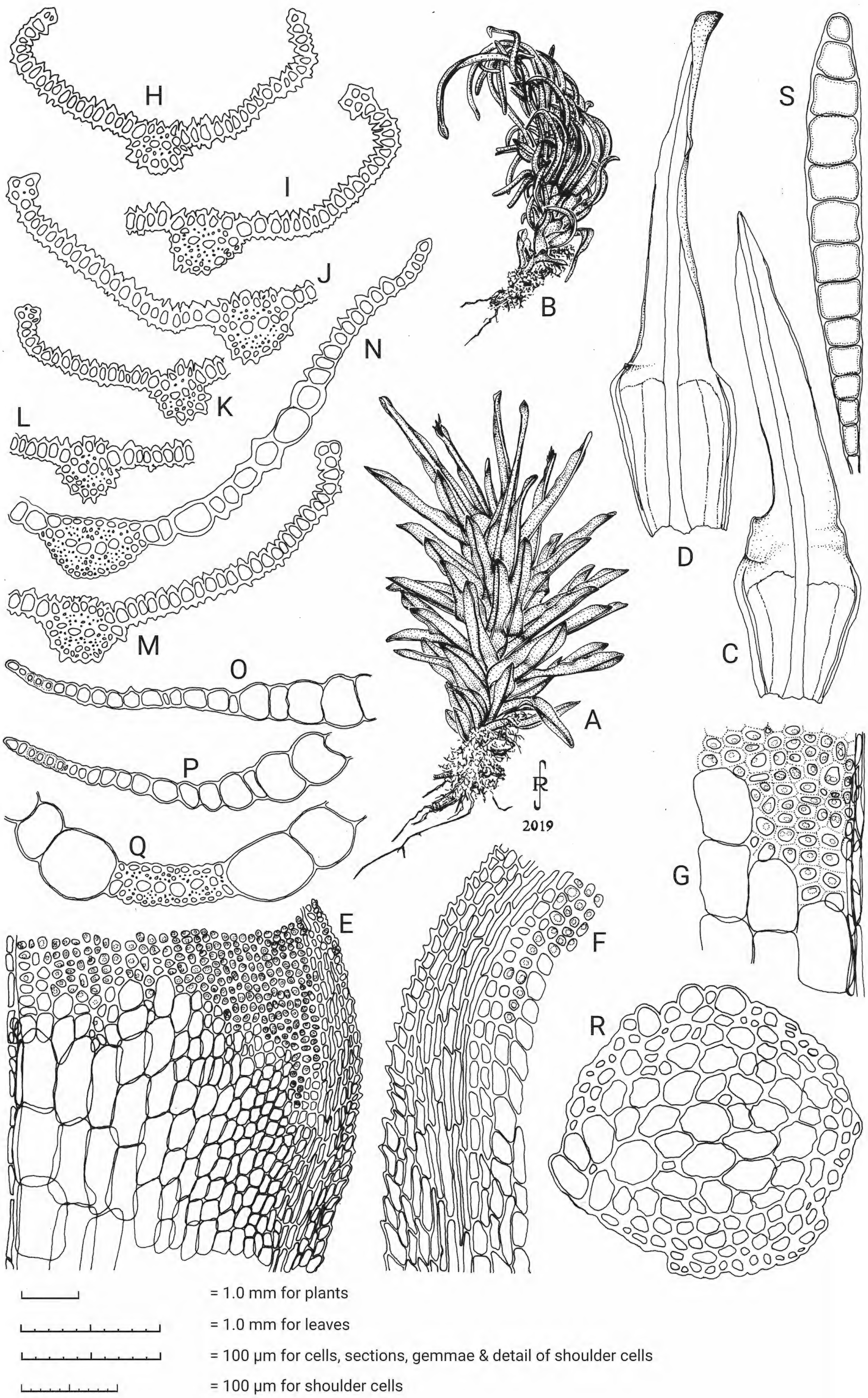

Fig. 8. *Calymperes moluccense* Schwägr. **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C:** Non-gemmiferous stem leaf. **D:** Gemmiferous leaf. **E:** Cells of leaf shoulder. **F:** Marginal cells of sheathing base of leaf. **G:** Upper cells of the lamina and lower chlorophyllous lamina at costa. **H–M:** Sections of chlorophyllose lamina and costa. **N:** Leaf section of distal margin of hyaline lamina. **O, P:** Sections of leaf margin of sheathing base of leaf. **Q:** Costal section near insertion. **R:** Stem section. **S:** Gemma. Drawn from: *D.A.Meagher & A.Cairns WT-182.*

9. *Calymperes motleyi* Mitt. ex Dozy & Molk., *Bryol. Jav.* 1: 48 (1856)

Original material: 'Habitat insulam Borneo, Laboean, prope Tanjong Koebong legit Motley, communicavit Mitten.'

Type: Indonesia: Borneo, *s.d.*, [1852], leg. *J. Motley s.n.* holotype: L-0060052, not seen, designated by Touw (2013); isotypes: NY01113972!d, ?MICH525294!d.

Illustrations: Eddy (1990: 129), Ellis and Tan (1999: 12).

Plants small, compact, dark green, to 8 mm tall, mostly shorter; in thin to dense tufts. Stems erect, to 8 mm tall, mostly shorter; rhizoids reddish brown. Leaves closely set, erect-spreading, folded and curved when moist, oblong or bluntly pointed above the base, not or only slightly dimorphic, lingulate to spathulate, without flared shoulders, upper limb typically wider than sheathing base, 1.0–2.0 mm long, 0.5–0.7 mm wide in mid limb, apex abruptly narrowed to a broadly rounded-mucronate tip; intramarginal cells lacking; margins entire, unistratose; cells of chlorophyllose lamina smooth to bluntly papillose, the surfaces convex, cells comparatively large, pellucid, (5–)8–10(–12) μm, walls moderately thickened, strongly convex adaxially, moderately so abaxially but with a median papilla or mammilla over lumen; chlorophyllose lamina cells in shoulder region and bordering the hyaline lamina with pronounced corner thickenings; hyaline lamina distinct, narrow, truncate to rounded distally, sometimes obliquely rounded; gemmiferous leaves constricted at the tips; costa strong, ending shortly below the apex, mostly bearing clusters of gemmae on adaxial tips; in section, costa covered by a layer of chlorophyllose cells, with about 4 large guide cells, adaxial and abaxial bands of substereid cells. Gemmae small, green to reddish, in brush-like tufts adaxially on costa tip; when dry, leaf tip usually not strongly infolded to adaxial surface as in *C. crassinerve*. Sporophytes rare. Calyptra about 2 mm long, spirally ribbed or folded. Seta reddish-yellow, 1–2 mm long. Capsules 0.5–1.0 mm long, shortly exserted; operculum about 0.5 mm long. Spores 26–31 μm in diameter, finely granular. (Fig. 9)

Diagnostic characters: *Calymperes motleyi* is easily recognised when bearing gemmiferous leaves by the characteristic shouldered appearance of the gemmiferous leaf tips with the apex of the costa included within the margins of the leaf tip. The species is similar to *C. crassinerve*, but there the leaves have rows of intramarginal cells, and also similar to *C. tenerum*, but that species has gemmae borne all around the leaf tip.

Distribution: In Australia, known from Northern Territory, Melville Island, north-eastern Queensland from Cape York as far south as Mackay (Fig. 16.9). Elsewhere, scattered through Seychelles, India, Thailand, Malesia, Polynesia, Oceania.

Habitat: Grows on trees, palms, rarely on dead wood and rock, mainly in low coastal and near-coastal forests, including mangroves, but up to about 400 m altitude.

Selected specimens seen: Queensland: Mackay: Kommo Toera Trail, Keeley's Road, Slade Point, about 6.5 km north of Mackay, 20 June 2016, *A.J.Franks AJF1606019* (BRI AQ0799544); Cairns: Lake Placid Tourist Park, Caravonica, 5 Mar 2016, *D.A.Meagher & A.Cairns WT-675* (BRI AQ1019827).

Etymology: After English engineer and naturalist James Motley (1822–1859), who collected the type in Borneo.

Typification: Touw (2013) noted that Menzel and Schultze-Motel (1990) cited a collection in NY (NY01113972!d, herb. Mitten) as the holotype, but he considered this to be an error. Len Ellis (in litt.) noted that Dozy and Molkenboer seem to have used Mitten's manuscript at the head of their account, which probably led Menzel and Schultze-Motel to state 'Mitt. in Dozy & Molk.,' as the authorship and therefore to consider the original material to be in Mitten's herbarium in NY rather than L.

MICH525294 seems to be a segregate of the NY material, but closer inspection is needed. The date of collection cited above is taken from NY01113972.

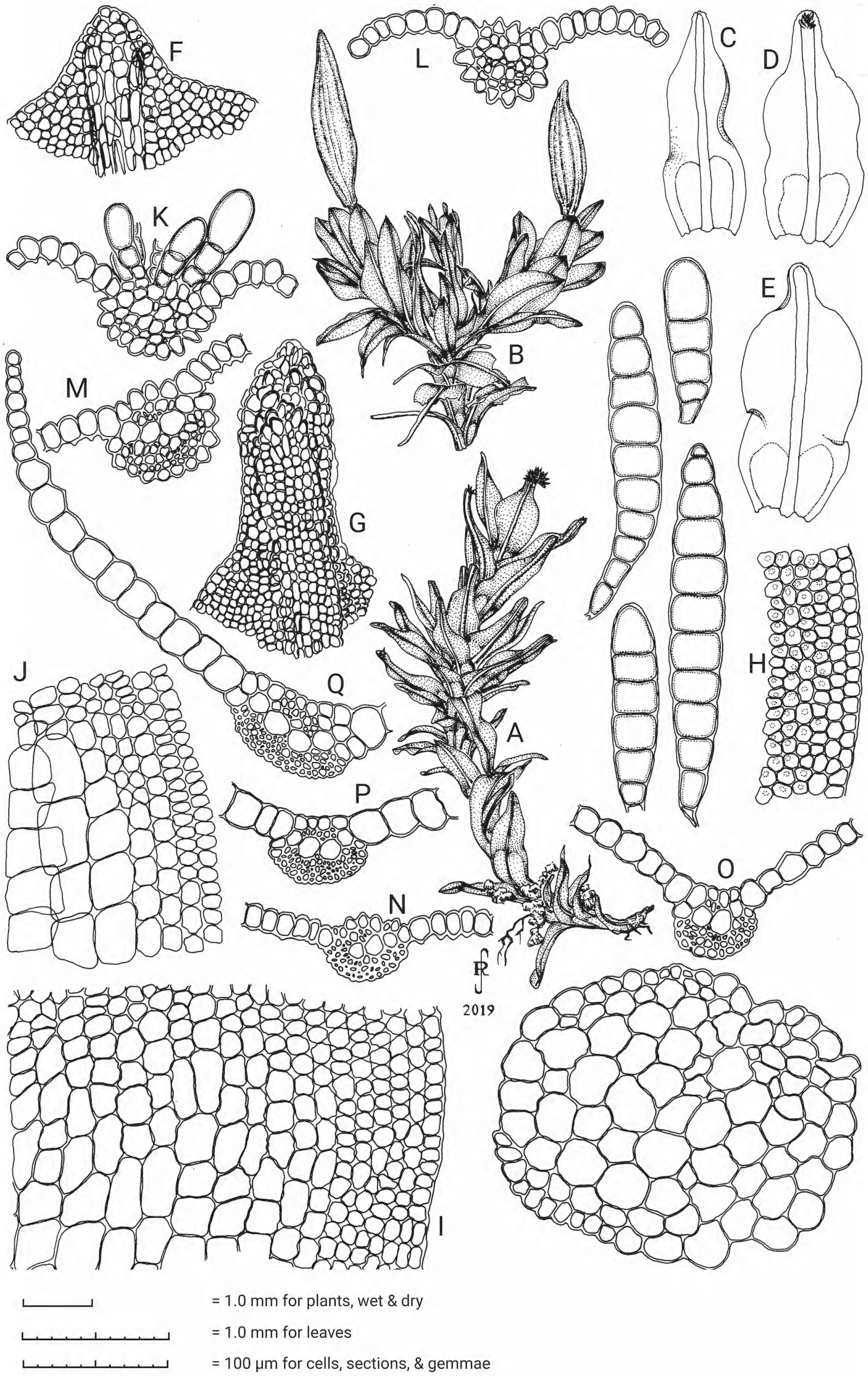

Fig. 9. *Calymperes motleyi* Dozy & Molk. **A:** Gemmiferous plant, drawn moist. **B:** Plant with sporophytes, drawn moist. **C:** Non-gemmiferous leaf. **D, E:** Gemmiferous leaves. **F:** Cells of non-gemmiferous leaf apex. **G:** Cells of apex of gemmiferous leaf, adaxial view. **H:** Mid limb marginal cells. **I, J:** Cells of distal end of hyaline lamina and lower chlorophyllose lamina. **K:** Section of apex of costa and leaf, with gemmae. **L, M:** Sections of chlorophyllose lamina and costa. **N–Q:** Sections of costa and hyaline lamina in sheathing base of leaf. **R:** Stem section. **Q:** Gemmae. Drawn from: *D.A.Meagher & A.Cairns WT-675* (A–E, H, I, K–Q); *A.J.Franks AJF1606019* (F, G, J).

10. *Calymperes porrectum* Mitt., *J. Linn. Soc. Bot.* 10: 172 (1868)

Original material: 'Hab. Tutuila, on bark. No. 10.'

Type: Samoa: Tutuila, Oct 1831, leg. *T. Powell 10.* Holotype: NY01114069!d; isotypes: BM000663161!d, MICH525295!d.

Illustrations: Eddy (1990: 106, 107), Ellis and Tan (1999: 14).

Plants robust, pale green, darker in older parts, 1.5–3.0 cm or taller, forming compact cushions or tufts. Stems mostly simple, erect; rhizoids reddish brown. Leaves strongly dimorphic; non-gemmiferous leaves translucent, oblong-lanceolate, recurved-squarrose from a broad sheathing base, 3–5 mm long, about 1.0 mm wide at shoulders; spreading-ascending when moist, patent when dry, from an ovate base narrowed above to a triangular-lanceolate acute apex; margins coarsely toothed with large single teeth; cells of chlorophyllose lamina smooth, thick-walled with rounded lumens, about 10 μm diameter but variable in size; intramarginal cells prominent, in leaf shoulders 6–10 cells intralaminal, continuing into the limb as a distinct intramarginal border extending to mid limb or beyond, composed of 2–3 rows of elongated, pellucid, thick-walled cells 2(–4) cells thick, the walls sinuose or pitted, reducing to an irregular series of elongated cells above. Costa of non-gemmiferous leaves smooth, in section with 4–8 guide cells sharply delimited from adaxial and abaxial stereid bands, with a differentiated epidermal layer. Gemmiferous leaves larger than non-gemmiferous leaves, stiffly erect from a broadly ovate to lanceolate sheathing base, 4–8 mm long, abruptly narrowing above the sheathing base to a subulate limb where the lamina narrows to meet the margin, the limb ending in a broader, rounded to spathulate, gemmiferous tip. Costa of gemmiferous leaves stouter than that of non-gemmiferous leaves, smooth adaxially, hispid abaxially with conically projecting cells and in section with a zone of substereids adjacent to the guide cells. Hyaline lamina large, ending at about shoulder level in an abrupt ± transverse demarcation line, or apices rounded and ± scalariform; gemmae reddish, tightly clustered on tips of gemmiferous leaves; gemma receptacle not developed. Sporophytes not seen. (Fig. 10)

Diagnostic characters: The strongly dimorphic leaves, non-gemmiferous leaves that are patent when dry and gemmiferous leaves stiffly erect wet or dry, make for ready identification. Microscopically, the coarsely toothed non-gemmiferous leaves with the teeth single and mostly multicellular, smooth chlorophyllose lamina cells and prominent intramarginal cells are diagnostic. The species is also similar to *C. couguiense*, which is a smaller plant with spathulate leaves and leaf margins irregularly denticulate, not coarsely serrate.

Distribution: In Australia, known from north-eastern Northern Territory and Cape Tribulation in Queensland (Fig. 16.10). Elsewhere, known from India, Sri Lanka, Malesia, the Philippines, Papua New Guinea, Oceania to the Society Islands. First reported for Australia by Reese and Stone (1987).

Habitat: Grows on tree trunks, moist rock ledges, in vine forests, at low altitudes, with an average annual rainfall of 3000–4000 mm.

Selected specimen seen: Queensland: Cook: Cape Tribulation, Noah Creek, 24 June 1982, *I.G.Stone 19318* (MEL 2245591).

Etymology: Latin *porrectum* (spread out, extended), probably referring to the elongate stems, or possibly the patent leaves when dry.

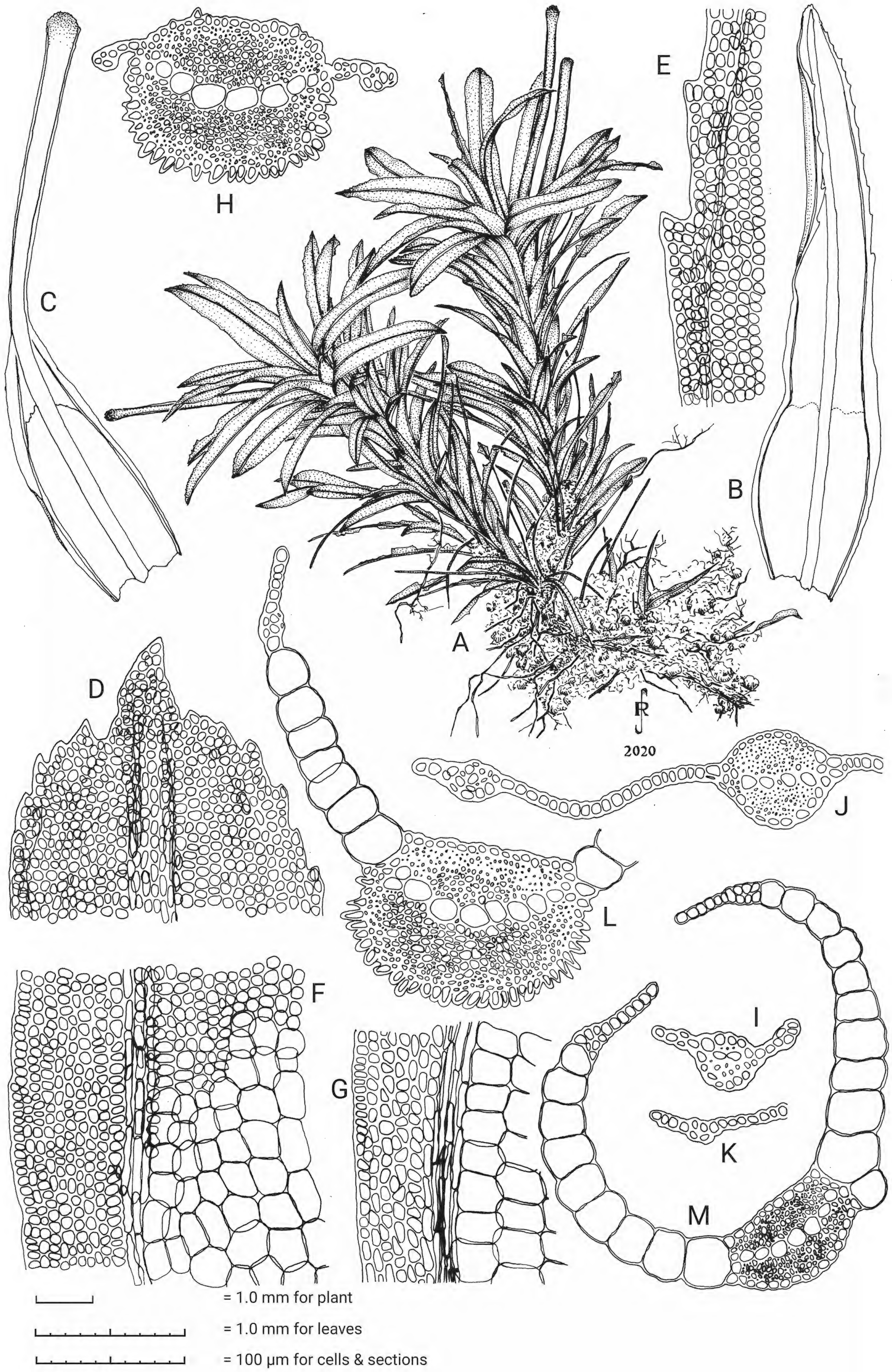

Fig. 10. *Calymperes porrectum* Mitt. **A:** Habit of plants, drawn moist. **B:** Non-gemmiferous leaf. **C:** Gemmiferous leaf. **D:** Cells of apex of non-gemmiferous leaf, abaxial view. **E:** Cells of serrate upper limb margin, with intramarginal cells. **F:** Cells of upper sheathing leaf base with intramarginal cells and hyalocysts of the hyaline lamina. **G:** Cells of lower margin of sheathing base. **H:** Section of limb of gemmiferous leaf. **I:** Section of apex of non-gemmiferous leaf. **J:** Section of limb of non-gemmiferous leaf, with intramarginal cells. **K:** Section of leaf margin with intramarginal cells. **L:** Section of sheathing base of gemmiferous leaf. **M:** Section of sheathing base of non-gemmiferous leaf. Drawn from: *I.G.Stone 19318*.

11. *Calymperes serratum* A.Braun ex Müll.Hal., *Syn. Musc. Frond.* 1: 527 (1849)

Original material: 'Patria. Java: Junghuhn.'

Type: Indonesia: Java, 1835–1849, *Junghuhn s.n.* holotype: ?B (presumed destroyed); isotypes: BM000851693!d, BM000851691!d *p.p.* (right-hand specimen only).

var. ***serratum***

Illustrations: Brotherus (1909: 379), Eddy (1990: 100, 101), Reese and Lin (1991: 330), Ellis and Tan (1999: 16).

Plants dark green to olive-green; forming low, tangled, grass-like tufts or mats. Stems erect, stemless to very short, several plants often seeming to arise from a single point source; rhizoids dark red to blackish purple; with dense tufts of elongate axillary hairs to 350–600 μm in length, the lower cells elongate rectangular, 5–10' longer than wide, median to upper cells 2–3' longer than wide. Leaves monomorphic; linear, (5–)10–15 mm long, 0.2–0.4 mm wide, ribbon-like from a short sheathing base slightly wider than the limb, slightly narrowed above the shoulders but not distinctly petiolate, straight when moist, curled when dry, margins irregularly serrate above; unistratose from the insertion to shortly above the shoulder then thickened and distinctly bordered almost to apex; borders ± trigonous in section, marginal stereome present or lacking, or a few stereids only, surrounded by chlorocysts; leaf shoulders unistratose, ± serrate by projecting cell ends; intramarginal cells in leaf sheath variable, ± distinct and up to 4 cells wide; costa percurrent or ending just below apex, ± smooth, plane adaxially, rounded-keeled abaxially, with (1–)2(–3) series of guide cells, thick stereid bands adaxially and abaxially, and an epidermal layer of lamina-like cells; lamina cells small, 5–7 μm wide, thick-walled, of variable shape, corners rounded, ± smooth; hyaline lamina variable, not clearly demarcated from chlorophyllose lamina cells, merging into chlorophyllose lamina. Gemmipars present, sparse, branching, ridged, papillose, reddish, on abaxial surface of distal lamina. Sporophytes rare. Calyptra about 4 mm long. Seta red to dark red, 4–6 mm long. Capsules emergent, about 2 mm long; operculum about 1 mm long. Spores 26–36 μm in diameter, smooth to inconspicuously granular. (Fig. 11)

Diagnostic characters: The species is similar in appearance to *Calymperes lonchophyllum* but differs in its indistinctly demarcated hyaline lamina and the short cells of the axillary hairs, although the cell length appears to be rather variable and might not be a reliable distinguishing feature. In the Australian material examined, the distinction in cell size of the axillary hairs is certainly not as clear cut as depicted by Akiyama and Reese (1992). In both *C. serratum* and *C. lonchophyllum* gemmae may occur on gemmipars along the upper margins and chlorophyllose lamina, an unusual feature in *Calymperes*, where the gemmae are usually borne at the leaf tips (Reese 2001). *Calymperes serratum* var. *subulatum* (E.B.Bartram) L.T.Ellis has relatively smaller cells in the chlorophyllose lamina, usually narrowly linear leaves, and usually longer cells in the axillary hairs (Ellis 2020). It is known from New Guinea, New Caledonia and other Pacific islands, and should be kept in mind when examining Australian material.

Distribution: In Australia, occurs in north-eastern Queensland from Windsor Tableland to Tully (Fig. 16.11). Elsewhere known scattered from tropical Africa, Sri Lanka, Thailand, China, Malesia, the Philippines, Papua New Guinea, to Polynesia, Fiji, New Caledonia.

Habitat: Grows on trees in rainforest to about 1000 m altitude.

Selected specimen seen: Queensland: Cairns: Mossman Gorge, Daintree National Park, 6 km west of Mossman. 26 Aug 1999, *H.Streimann & T.Pócs 64457* (BRI AQ0717259).

Etymology: Latin *serratum* (saw-toothed), referring to the serrated upper margins of the leaves.

Typification: BM000851693 is annoted 'Calymperes serratum n. sp. Java' in ink and 'A Braun' and 'serratum isotype' in pencil, so it is undoubtedly an isotype. BM000851692 is from Schimper's herbarium and is much more compact than the preceding specimen, so we doubt that it is an isotype. BM000851691 is from Hooker's herbarium, ex Junghuhn's herbarium ('in horto Academiae Lugduno Batavae') and is annotated 'Ins. Java legit. Dr. Fr. Junghuhn, so it too is undoubtedly an isotype, but according to a pencilled note, we think in Bill Reese's hand, only the right-hand of the two specimens on the sheet is *C. serratum*, the other being *C. lonchophyllum*. BM000518004 is in Herb. Hooker ex herb. Dozy & Molk., annotated 'Calymperes serratus A.Br.'; there is no evidence that it is type material.

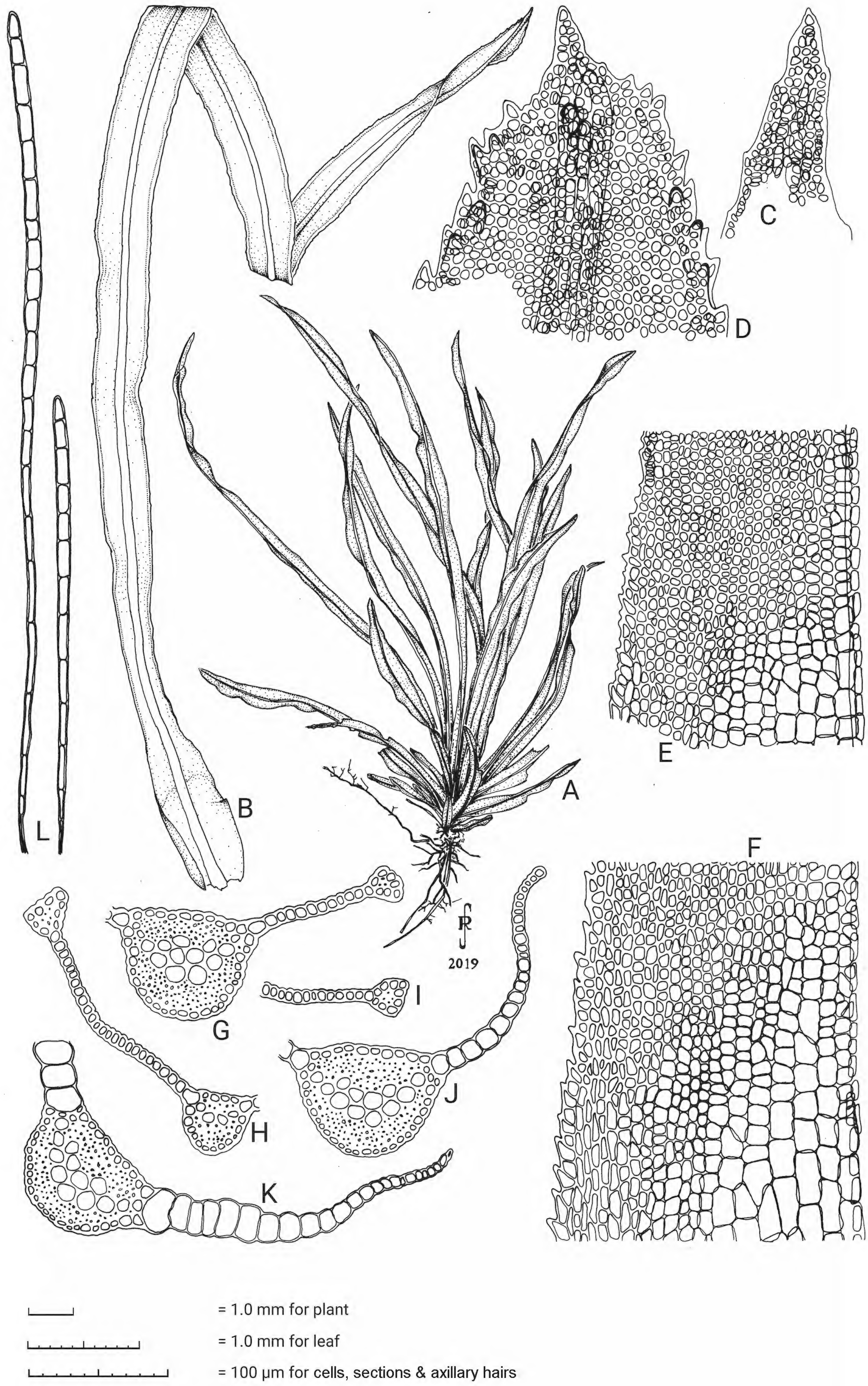

Fig. 11. *Calymperes serratum* A.Braun ex Müll.Hal. **A:** Habit of plant, drawn moist. **B:** Leaf. **C:** Cells of leaf apex, adaxial view. **D:** Cells of leaf apex, abaxial view. **E, F:** cells of upper hyaline lamina. **G, H:** Sections of chlorophyllose lamina. **I:** Section of chlorophyllose lamina margin. **J, K:** Sections of sheathing base of leaf. **L:** Axillary hairs. Drawn from: *H.Streimann and T.Pócs 64457*.

12. *Calymperes strictifolium* (Mitt.) G.Roth, *Hedwigia* 51: 127 (1911). *Syrrhopodon strictifolius* Mitt., *Fl. Vit.* 388 (1873)

Original material: 'Samoan Islands, Tutuila (Powell!).'

Type: Samoa, Tutuila, c. 1831, *T. Powell s.n.* holotype (mounted on 2 sheets): NY (NY01127836!d / NY01127837!d); isotypes: PC0100852!d; BM000663170!d.

Illustrations: Eddy (1990: 112), Reese and Lin (1991: 338), Ellis and Tan (1999: 17).

Description: Plants to about 10 mm tall, occasionally more, glaucous green to brownish green, in dense wiry tufts. Stems erect, simple; rhizoids brown. Leaves essentially monomorphic, erect flexuose when moist, little altered but slightly incurved when dry; most or all leaves gemmiferous, oblong-ligulate to broadly linear above a broadened ovoid base, 3–4(–5) mm long, 0.3–0.55 mm wide in sheathing base and 0.2–0.3 mm wide in limb, ending abruptly in a rounded-truncate tip; margins thickened, strongly warty-rugulose with multicellular nodules of chlorophyllose cells; intramarginal cells ± distinct in sheath and base of limb, 2–4 cells wide and 3–5 cells intralaminar, weakly developed and ± hidden in thickened upper leaf margin; cells of limb small, 5–6 μm wide, ovoid-rectangular, walls moderately thickened, inconspicuously pluripapillose; hyaline lamina large, sharply defined, scalariform. Costa stout, warty-rugulose with multicellular excrescences like those of leaf margins, in section with 4–6 guide cells, thick adaxial and abaxial stereid bands and epidermal layer of chlorophyllose cells. Gemmae borne at apex of leaf on adaxial side of costa. Sporophytes not seen in Australian material. (Fig. 12)

Diagnostic characters: The warty, rugose leaf margins and costa are unique and, together with the scalariform hyaline lamina with ± inflated hyalocysts, particularly distally, make the species readily identifiable, even with only a hand lens.

Distribution: North-eastern Queensland from Innisfail to Cairns (Fig. 16.12). Elsewhere known from China, Taiwan, Malesia, the Philippines, Papua New Guinea, French Polynesia, New Caledonia. Eddy (1990) noted that the species is widely scattered in its range but uncommon generally, although locally frequent in New Guinea and adjacent islands.

Habitat: Grows on tree trunks, rotting wood and rocks in wet to very wet mesophyll vine forest, typically in densely shaded, moist sites below 750 m altitude.

Selected specimen seen: Queensland: Cairns: near Cairns, 1 Aug 1890, *C.J.Wild s.n.* (BRI AQ0719287).

Etymology: Latin *strictus* (drawn together, tight) + *folium* (leaf), referring to the densely tufted leaves.

Typification: NY01127836 and NY01127837 (which are on a single sheet) and BM000663170 are stamped 'loaned to Dr. G. Roth for drawing for the Aussereuropaischen Laubmoose' and 'type'. NY001127836 appears to be a single stem sent to E.B. Bartram and subsequently returned.

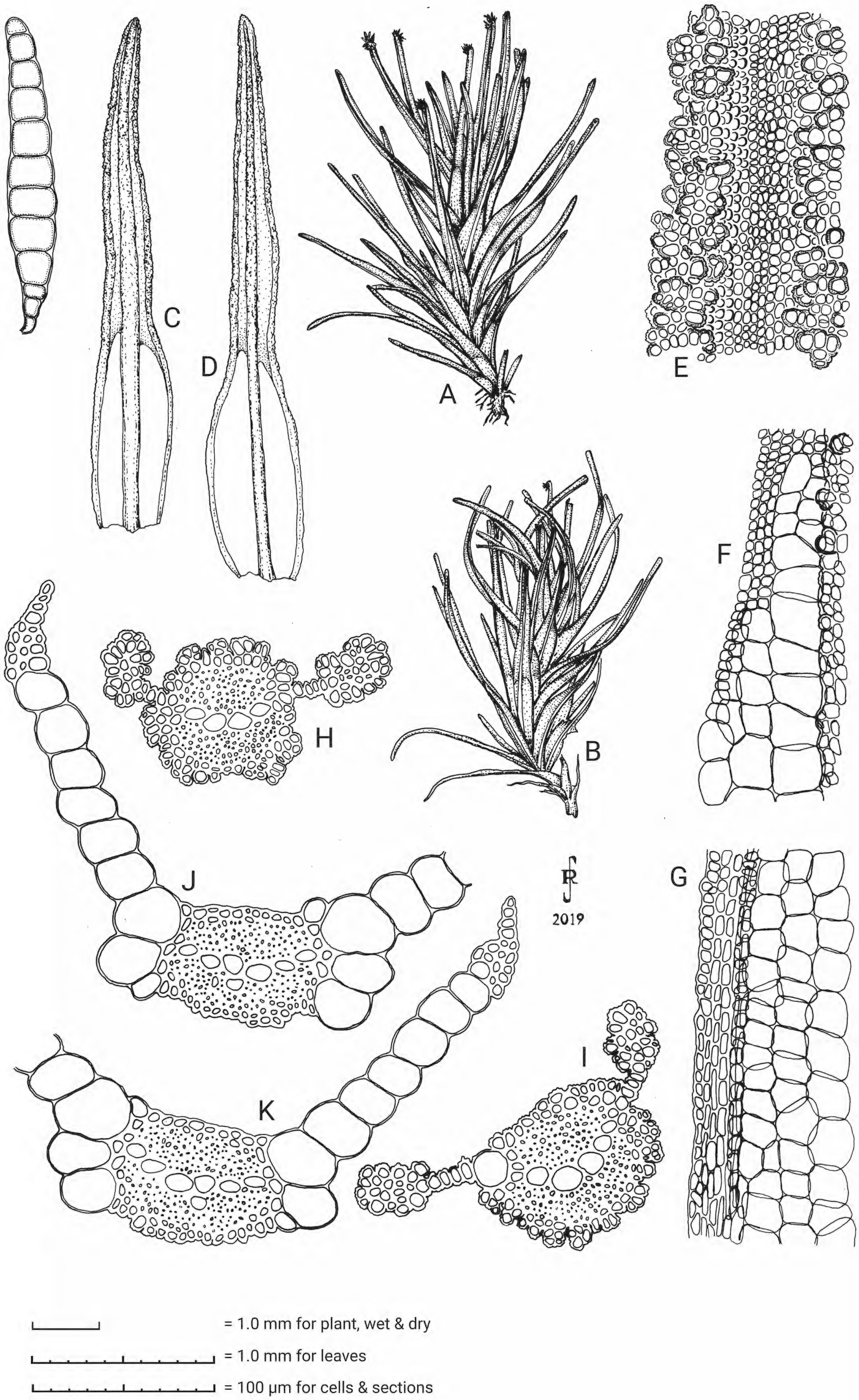

Fig. 12. *Calymperes strictifolium* (Mitt.) Roth. **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C, D:** Leaves, abaxial view. **E:** Cells of leaf margin (left), chlorophyllose lamina and costa (right) of limb. **F:** Distal end of hyaline lamina. **G:** Cells of sheathing base with intramarginal cells. **H, I:** Sections of chlorophyllose lamina. **J, K:** Sections of sheathing base of leaf. **L:** Gemma. Drawn from: *C.J. Wild s.n.*

13. *Calymperes subintegrum* Broth., *Bot. Tidsskr.* 24: 119 (1901)

Original material: 'Lem Dan, on rocks and trees near the Sea.'

Type: Thailand: Koh Chang (island), Lem Dan, 7 Jan 1900, *J. Schmidt 23*. holotype: HBR, not seen; isotypes: BM000518251!d, NY01114094!d, PC0148379!d.

Illustrations: Eddy (1990: 110, as *C. schmidtii*), Ellis and Tan (1999: 17).

Plants small, to about 0.5 mm tall, mostly dark green to brownish, forming loose to compact turfs. Stems erect, simple; rhizoids brown. Leaves strongly dimorphic; non-gemmiferous stem leaves lingulate to spathulate, 2–3 mm long, 0.5–0.6 mm wide, spreading, sheathing base narrower than limb; apex rounded-obtuse; straight and involute when moist, loosely uncinate to curled-contorted when dry; margins weakly dentate or entire, often inflexed; with distinct intramarginal cells innon-gemmiferous leaves, the intramarginal cells marginal or almost so, in the shoulders 1(–3) cells intramarginal, bounded on outer edge by a row of rectangular, pellucid cells which may project as serrations; chlorophyllose lamina cells ± quadrate, thin-walled, 6–8 μm wide, conically prominent on adaxial side, papillose on abaxial side. Gemmiferous leaves to 6 mm long, stiffly erect from an ovate sheathing base, the limb linear; costa thick, with chlorophyllose lamina narrow to the spathulate apex. Costa of non-gemmiferous leaves narrow, roughened by conically projecting epidermal cells, in section with 4–5 guide cells, adaxial and abaxial stereid bands; costa of gemmiferous leaves stronger, hispid on both surfaces with conical to sub-spiniform epidermal cells; guide cells in irregular rows with adaxial and abaxial thin-walled substereids. Gemmae arising from the adaxial surface of the leaf apex. Sporophytes not seen in Australian material. (Fig. 13)

Diagnostic characters: Similar in general appearance to *Calymperes couguiense* but differs in its smaller stature and in having the delicate hyaline marginal cells forming teeth at mid leaf and below, particularly in the shoulder region, although these cells may not be present on all leaves. Reese *et al.* (1986), Menzel and Schutze-Motel (1990) and Eddy (1990) treated *C. subintegrum* as a synonym of *C. schmidtii* Broth. However, Ellis (1991) showed that the two were different species.

Distribution: In Australia, known in north-eastern Queensland from the Paluma Range, north of Townsville, to the Daintree River (Fig. 16.13). Elsewhere known from Sri Lanka, Thailand, China (Hainan Island), Malesia, Philippines, Polynesia, New Caledonia.

Habitat: Grows on soil and rock, sometimes on tree bases and rotting wood in rainforests and wet sclerophyll forest up to about 850 m.

Selected specimens seen: Queensland: Cairns: Graham Range communication towers access road, Bramston Beach, 07 Nov 2014, *A.J.Franks AJF1411003* (BRI AQ0910205); Cassowary Coast: Weir on Boulder Creek, uphill from gate at Alligator's Nest, north of Tully, 7 May 2014, *D.A.Meagher & A.Cairns WT-352* (BRI AQ1017016).

Etymology: Latin *sub* (incompletely) + *integrum* (whole, entire), referring to the subentire leaves.

Typification: The collection number and date are taken from the isotypes. NY01114094 is annotated 'Koh Chang, Klong Majum' and the collecting number 23 is included, indicating that it is also an isotype.

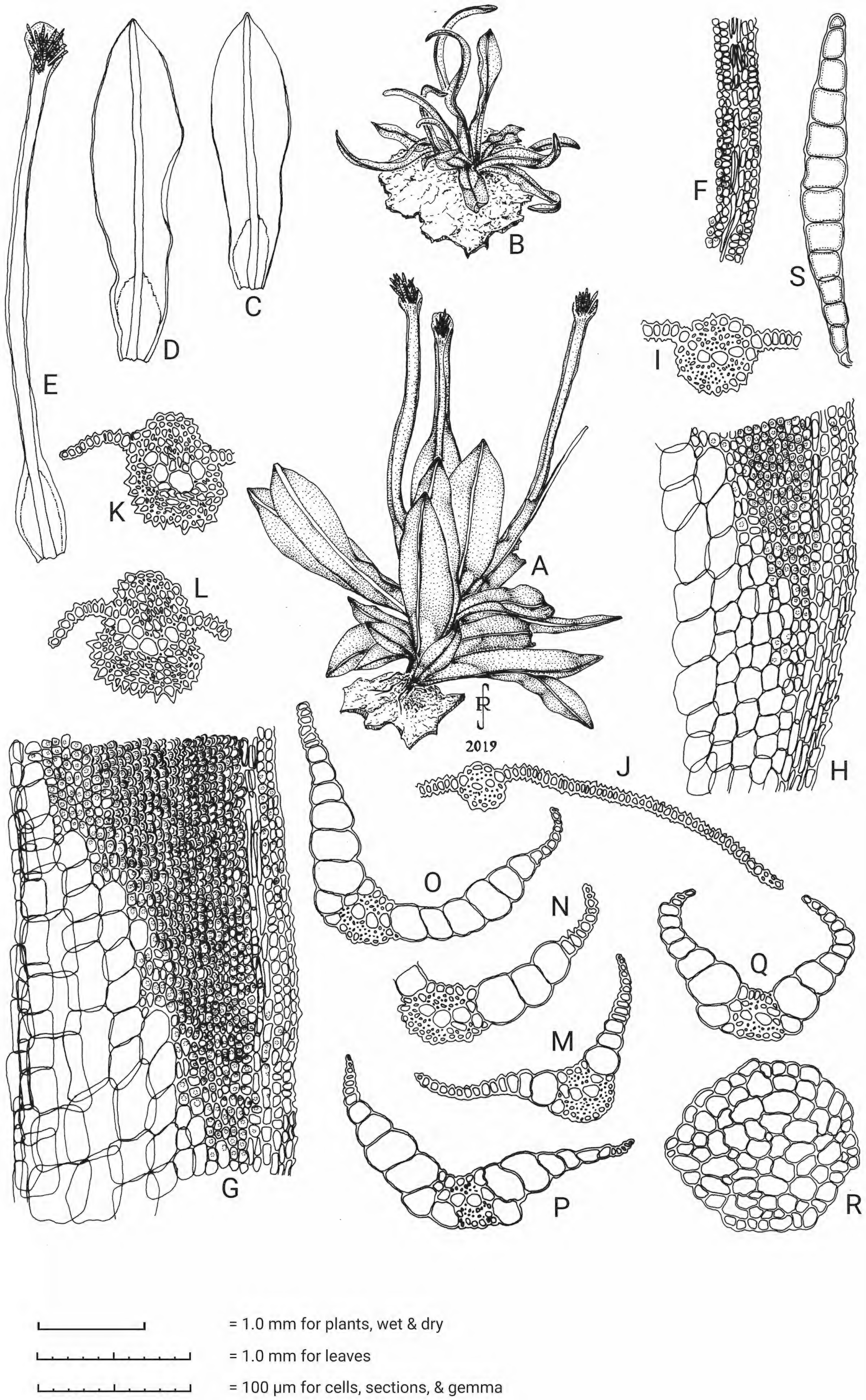

Fig. 13. *Calymperes subintegrum* (Mitt.) G.Roth. **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C, D:** Non-gemmiferous leaves. **E:** Gemmiferous leaf. **F:** Cells of mid lamina margin of non-gemmiferous leaf, with intramarginal cells. **G:** Cells of hyaline lamina and leaf margin in shoulder region of leaf base. **H:** Marginal cells of lower sheathing base of leaf. **I:** Section of costa of non-gemmiferous leaf. **J:** Section of non-gemmiferous leaf with intramarginal cells. **K, L:** Sections of limb of gemmiferous leaf. **M–Q:** Sections of sheathing leaf base. **R:** Stem section. **S:** Gemma. Drawn from: *A.J.Franks AJF1411003*.

14. *Calymperes taitense* (Sull.) Mitt., *J. Linn. Soc., Bot.* 10: 172 (1868). *Syrrhopodon taitensis* Sull., *U.S. Expl. Exped., Musci* 18, pl. 4A (1859)

Original material: 'Hab. Tahiti, Society Islands.'

Type: French Polynesia: Tahiti, Aug–Oct 1839, *W. Sullivant s.n.* holotype: FH01146523, not seen; isotypes: BM000851987!d, BM000518493!d, BM000518474!d.

Illustrations: Sullivant (1859: plate 4A), Eddy (1990: 113), Reese and Lin (1991: 336), Ellis and Tan (1999: 19).

Plants robust, dark green to blackish, 10–25 mm tall, forming loose tufts or mats. Stems uncinate, simple or forked, often sprawling; rhizoids brown to reddish brown or dark purple. Leaves ± uniform, spreading ascending when moist, loosely contorted-curled when dry, linear with ± parallel sides in limb from a slightly broader base, 3.5–7.0 mm long, 0.35–0.5 mm wide in limb, abruptly narrowed to a rounded-obtuse to mucronate or proboscid apex; margins thickened, often conspicuously toothed above, rounded-triangular in section, without an internal stereome; leaf shoulder with distinct intramarginal cells, pellucid, 2–4 cells wide, continuing as a broad unistratose band in the sheathing base; hyaline lamina sharply delimited, distal margins ± rounded scalariform, with the lamina shortly decurrent down the costa, upper margin irregular, often with files of hyaline cells extending upwards, interlocking with the cells of the chlorophyllose lamina. Chlorocysts small, irregularly rounded, about 5 μm wide in upper limb, slightly larger near hyaline lamina, smooth abaxially, rounded-mammillose adaxially. Costa smooth or nearly so, ending below the apex; in section with 5–10 guide cells and occasional secondary guide cells adaxially, adaxial and abaxial stereid bands and an epidermal layer of chlorophyllose lamina cells. Gemmiferous leaves with a well-developed proboscis with narrowly revolute margins; gemmae borne adaxially on leaf tips. Sporophytes not seen in Australian collections. (Fig. 14)

Diagnostic characters: *Calymperes taitense* is very distinctive by its large size, dark colour and (in Australia) its mostly streamside habitat. Confusion may occur with *C. afzelii*, but that is a smaller species with acutely mammillose chlorophyllose lamina cells, and the distal margins of the hyaline lamina in *C. afzelii* are scalariform and do not interlock with the cells of the chlorophyllose lamina. Australian plants agree in leaf length with specimens described by Ellis and Tan (1999) from the Philippines, although Sullivant gave the length as 4–5 lines (8.5–10.5 mm).

Distribution: In Australia, known from north-eastern Queensland from Bloomfield River south to Ingham (Fig. 16.14). Elsewhere known from Central West Africa, Comoros Islands, Madagascar, Réunion, Andaman Islands, Seychelles, southeast and east Asia, China, Philippines, Malesia, Polynesia, Oceania.

Habitat: Grows on tree trunks and boulders in rainforests, particularly along streams, up to about 1000 m.

Selected specimen seen: Queensland: Cassowary Coast: Mount Mackay State Forest, near Tully. 22 June 1984, *I.G.Stone 22511* (BRI AQ0873537).

Etymology: Taiti + *–ense* (coming from), after Taiti (Tahiti), the location of the type collection. The epithet is often rendered incorrectly as *tahitense*. However, it is based on the legitimate spelling Taiti that was in common use in the 19th century, and therefore must not be altered.

Typification: This species was not listed by Sayre (1984) in her index to William Sullivant's moss herbarium, but it is listed in the online database of the Harvard University herbaria (HUH 2020), which indicates that it was identified as the holotype by Bill Reese. The US Exploring Expedition was at Tahiti from 13 August to 10 October 1939. BM000851987, ex herb. Bescherelle, is annotated 'U.S. Ex. Ex. Wilkes 1838–1842' and '*Syrrhopodon Taitense* Sp. Nov. Tahiti, Society Islands' and is annotated as an isotype by Bill Reese, although the collector is not stated. BM000518493 is a fragment taken from BM000851987 by Zen Iwatsuki for drawing. BM000518474 is also annotated as an isotype by Bill Reese, and the other annotations are identical to BM000851987.

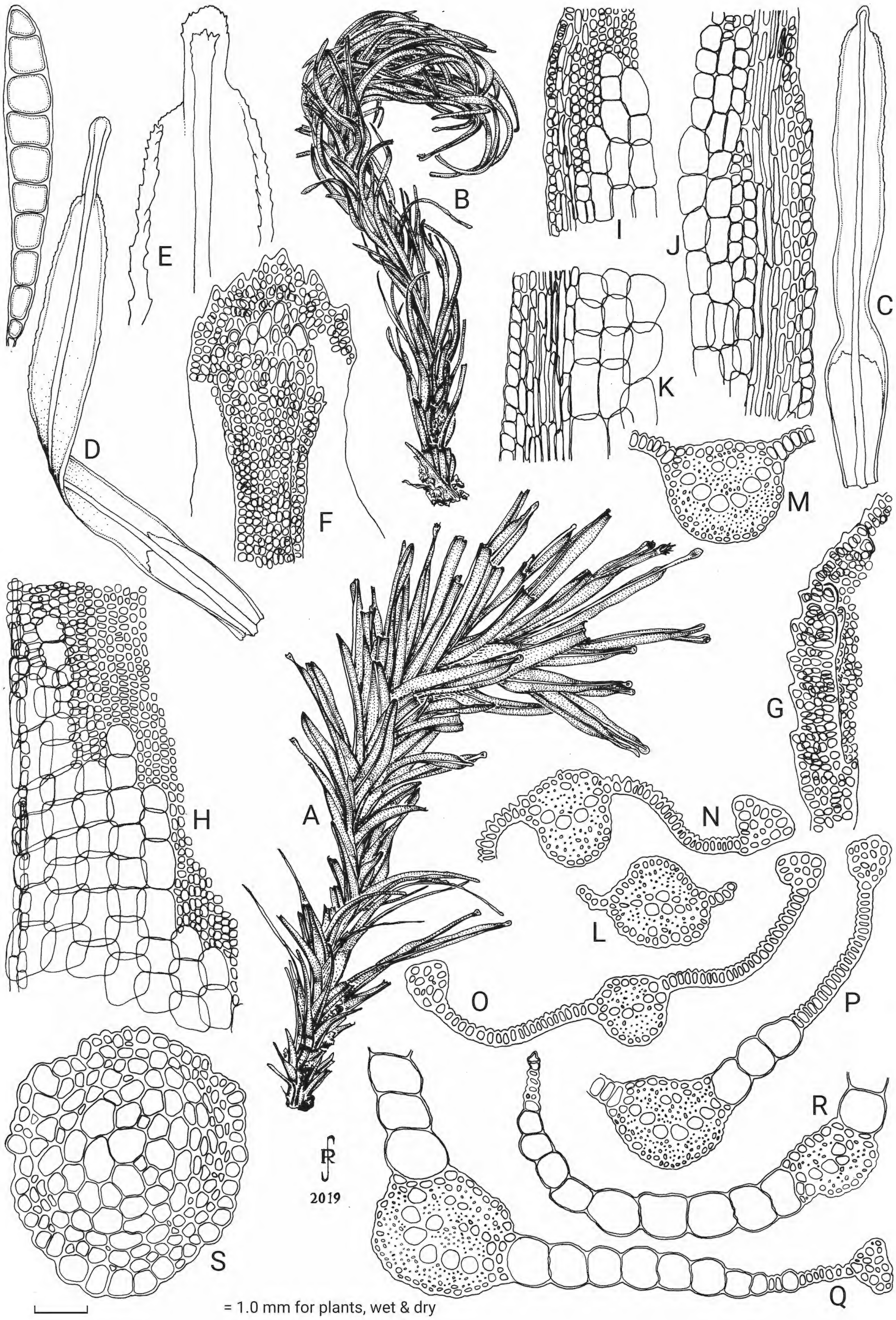

Fig. 14. *Calymperes taitense* (Sull.) Mitt. **A:** Habit of plant, drawn moist. **B:** Habit of plant, drawn dry. **C, D:** Leaves with proboscid apices. **E:** Leaf apex, adaxial view. **F:** Cells of leaf apex, adaxial view. **G:** Cells of leaf margin near apex. **H:** Cells of hyaline lamina. **I–K:** Marginal cells of hyaline lamina. **L:** Section of leaf proboscis. **M–O:** Sections of costa and chlorophyllose lamina. **P–R:** Sections of hyaline lamina. **S:** Stem section. **T:** Gemma. Drawn from: *I.G.Stone 22511.*

15. *Calymperes tenerum* Müll.Hal., *Linnaea* 37: 174 (1872)

Original material: 'Patria. Bengalia, Calcutta ad truncos arborum inter Lejeuniam: S. Kurz legit.'

Type: India: Kolkata, 1864–1873, *S. Kurz s.n.* holotype: ?B (presumably destroyed); isotype: BM000518466!d.

Illustrations: Eddy (1990: fig. 249); Reese and Lin (1991: fig. 53–58); Ellis and Tan (1999: fig. 10m–q).

Plants small, mostly less than 5 mm tall, pale to dark green, in thin to compact turfs. Leaves almost uniform, oblong to lanceolate, lingulate, (1.5–)2–3 mm long, not or scarcely widened in sheathing base; straight when moist, involute and curved and often ± secund when dry; leaf margins unistratose to slightly thickened with 1–2 rows bistratose, entire, composed of small quadrate chlorophyllose cells along margins of sheathing base, the cells with marked corner thickenings; chlorophyllose lamina cells thin-walled, 6–8 μm wide in upper limb, smooth or typically papillose abaxially with a small central papilla, bulging convex adaxially; intramarginal cells lacking; hyaline lamina small, narrow, rectangular, truncate or rounded distally, with 4–7 rows of large hyaline cells; gemmiferous leaves similar to non-gemmiferous leaves but costa shortly excurrent as a proboscis which bears gemmae all around the tip; gemmae smooth, green, clavate-fusiform, in pale globular clusters at leaf tips. Sporophytes infrequent in Australian collections. Calyptra 2.5–3.0 mm long, the base not or scarcely exceeding tips of perichaetial leaves. Seta reddish-yellow, short, 1.5–2.0 mm long. Capsule emergent, about 2.0 mm long; operculum 0.5 mm long. Spores 30–52 μm in diameter, finely granular or ± smooth. (Fig. 15)

Diagnostic characters: The small size of the plants, absence of intramarginal cells, narrow and truncate hyaline lamina, ± quadrate marginal cells in the leaf sheath, and dense globular clusters of pale gemmae borne all around the tip of the costa are diagnostic. Even when the gemmae are shed, the naked excurrent tip of the costa of gemmiferous leaves is distinctive. The only other species in Australia bearing gemmae all around a naked excurrent costa tip is *Calymperes erosum*, but in that species the leaves have rows of intramarginal cells. There is some similarity to *C. graeffeanum* and *C. motleyi*, but both have gemmae only on the adaxial surface of the gemmiferous leaf tips. If gemmiferous leaves are lacking, the hyaline lamina in *C. graeffeanum* is broader and has a scalariform apex, rather than a truncate apex as in *C. motleyi* and *C. tenerum*, and the leaf shoulders of *C. graeffeanum* are often somewhat toothed. *C. graeffeanum* also has row of intramarginal cells in the leaf base. Non-gemmiferous plants of *C. motleyi* and *C. tenerum* without sporophytes and gemmiferous plants lacking gemmae are almost indistinguishable, but such plants are very uncommon.

Distribution: In Australia, known from the Kimberley region of Western Australia, the northern Northern Territory, and north-eastern Queensland from Cape York to north of Rockhampton (Fig. 16.15). Elsewhere a pantropical species widespread around coastal regions of tropical Asia, lowland Malesia.

Habitat: Grows on trees, including mangroves, palms and shrubs, primarily in low coastal vegetation, but also inland, to about 500 m altitude.

Selected specimens seen: Queensland: South Kennedy: Yuibera Trail on way to Hidden Valley, Cape Hillsborough National Park, 03 July 2014, *A.J.Franks AJF1407033* (BRI AQ0910247); Cassowary Coast: Planted shoreline vegetation, Cardwell foreshore, 19 Sept 2012, *D.A.Meagher & A.Cairns WT-098A* (BRI AQ1016583).

Etymology: Latin *tenerum* (thin), referring to the narrow cells of the leaf lamina.

Typification: The holotype was probably destroyed in the bombing of the Berlin museum in 1943. BM000518466 is ex herb. Hampe and has annotations in ink that agree with the protologue. It is annotated as an isotype by Bill Reese.

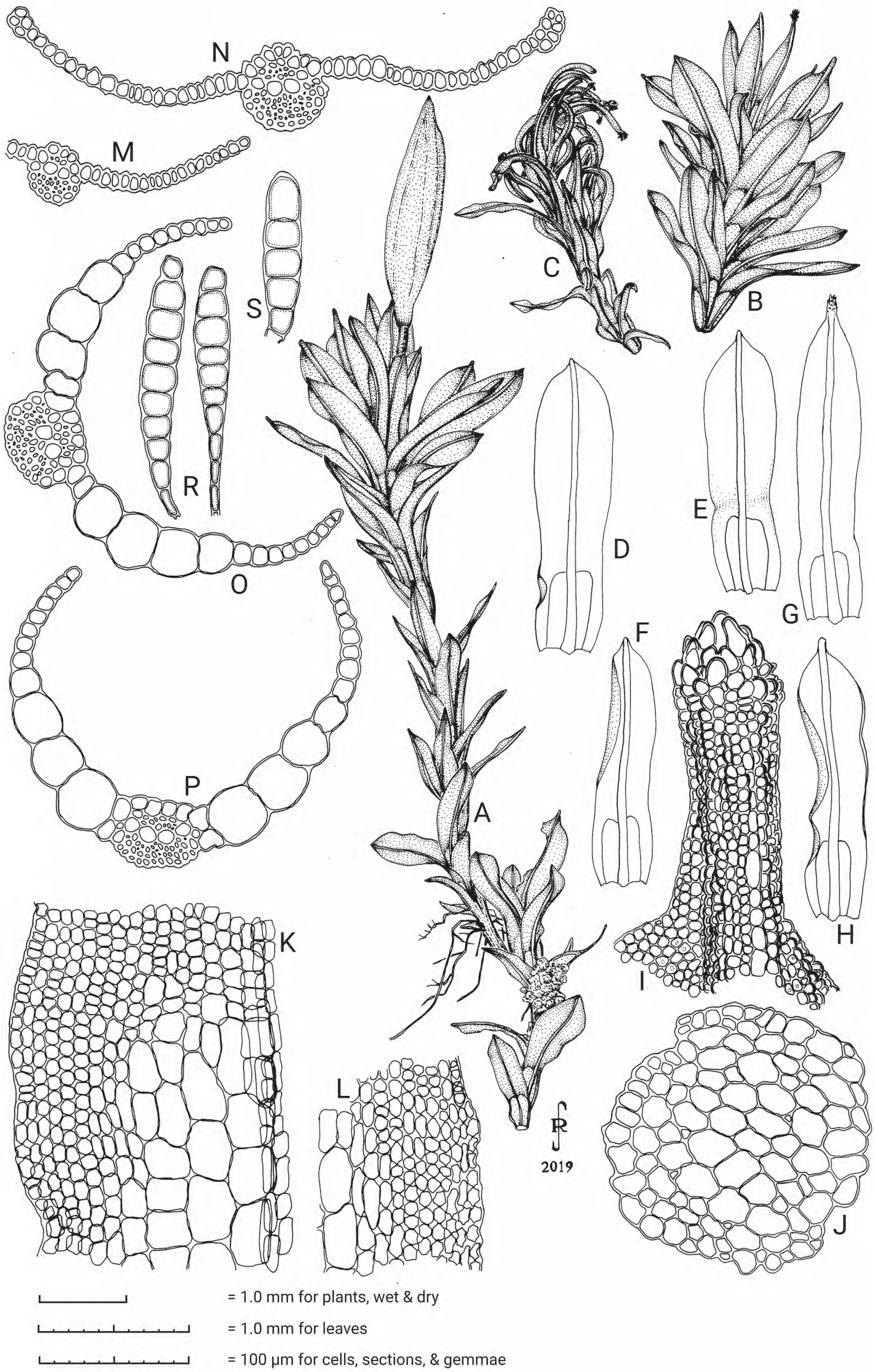

Fig. 15. *Calymperes tenerum* Müll.Hal. **A:** Habit of plant with sporophyte, drawn moist. **B:** Gemmiferous plant, drawn moist. **C:** Gemmiferous plant, drawn dry. **D-F:** Non-gemmiferous leaves. **G, H:** Gemmiferous leaves. **I:** Cells of leaf apex, abaxial view. **J:** Cross-section of stem. **K:** Upper cells of hyaline lamina. **L:** Cells of margin of leaf sheath. **M, N:** Sections of chlorophyllose lamina. **O, P:** Sections of sheathing leaf base. **Q:** Stem section. **R, S:** Gemmae. Drawn from: *A.J.Franks AJF1407033*.

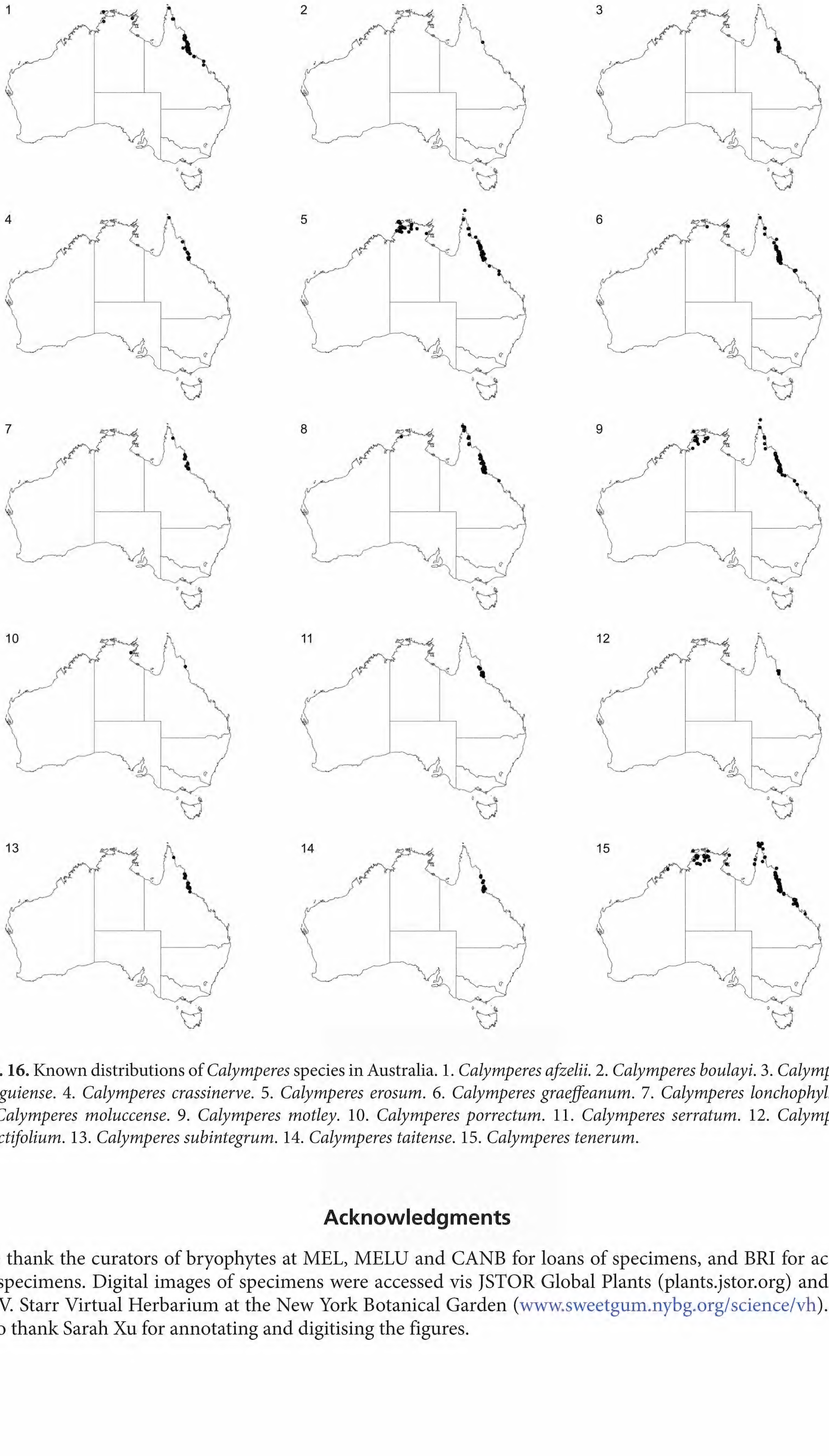

Fig. 16. Known distributions of *Calymperes* species in Australia. 1. *Calymperes afzelii*. 2. *Calymperes boulayi*. 3. *Calymperes couguiense*. 4. *Calymperes crassinerve*. 5. *Calymperes erosum*. 6. *Calymperes graeffeanum*. 7. *Calymperes lonchophyllum*. 8. *Calymperes moluccense*. 9. *Calymperes motley*. 10. *Calymperes porrectum*. 11. *Calymperes serratum*. 12. *Calymperes strictifolium*. 13. *Calymperes subintegrum*. 14. *Calymperes taitense*. 15. *Calymperes tenerum*.

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The family Calymperaceae (Bryophyta) in Australia. Part 3: The genus *Mitthyridium*

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Abstract

Each of the nine *Mitthyridium* (Mitt.) H.Rob. species known from Australia is described and illustrated in detail, and a key to species and distribution maps are provided.

Introduction

This is the third paper in a series constituting a synopsis of the moss family Calymperaceae in Australia. The first paper (Seppelt *et al.* 2021a) provided a key to the genera of Calymperaceae in Australia, and the second paper (Cairns *et al.* 2021) treated the genera *Arthrocormus* Dozy & Molk., *Exostratum* L.T.Ellis and *Leucophanes* Brid. This paper treats the genus *Mitthyridium* (Mitt.) H.Rob., of which nine species are currently known from Australia.

In the following treatment the descriptions are based on the work of Nowak (1980), Reese *et al.* (1986a, 1986b), Eddy (1990) and Reese and Stone (2012), our own observations in the field, and our studies of a representative sample of collections held in Australian herbaria, supplemented by our own collections. The notation !d indicates that a high-resolution digital image of a specimen has been seen via JSTOR Global Plants (www.plants.jstor.org).

Mitthyridium (Mitt.) H.Rob., *Phytologia* 32: 432 (1975). *Thyridium* Mitt., *J. Linn. Soc. Bot.* 10: 188 (1868), *non* Nitschke (1867).

Type species: *Syrrhopodon fasciculatus* Hook. & Grev. (=*Mitthyridium fasciculatus* (Hook. & Grev.) H.Rob.

Plants with creeping primary stems and ascending branches, forming mats or low tufts, green or yellowish-green; rhizoids abundant on primary stems, dark reddish-brown to purple. Branch leaves lanceolate to

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acuminate or oblong-linear, flexuose-spreading from a sheathing hyaline base, the lamina unistratose and usually markedly flexuose or undulate, variously shrunken and crisped when dry; margins conspicuously bordered below by a flat, unistratose border which narrows upwards and often vanishes well below leaf apex, usually denticulate with projecting cells; apex variable from acute to obtuse. Upper lamina cells small, obscure or pellucid, pluripapillose. Cells of marginal border linear, prosenchymatous (thick-walled), smooth or with sparse papillae. Leaf base composed mainly of a pair of lattices of much larger thin-walled, rectangular hyaline cells (hyaline lamina), usually sharply differentiated from chlorophyllose lamina cells, often with pores. Costa well developed, ending in or just below the apex, smooth in lower half, sometimes roughened in acumen; in section usually with 4 guide cells, well-developed adaxial and abaxial stereid bands and differentiated epidermal layers, typically resembling epidermal cells in upper limb. Dioicous. Male and female plants similar. Sporophytes rarely produced, terminal at branch tips. Perichaetia inconspicuous, inner bracts not usually much different from normal leaves. Seta slender, elongate, smooth. Capsule exserted, cylindrical, similar to that of *Syrrhopodon* in form and peristome; operculum with a long slender rostrum. Calyptra cucullate, deciduous. Gemmae fusiform-clavate, usually produced in abundance from adaxial or both sides of the tip of the costa, sometimes enclosed in a funnel-shaped expansion of the leaf apex.

Etymology: Mitten + *Thyridium* (from Greek *thyridion*, a little door or window), referring to William Mitten, the author of the original but illegitimate name *Thyridium*, and the transparent lattice of thin-walled hyaline cells in the leaf base.

Notes: When Mitten (1868) erected the genus *Thyridium*, that name was pre-dated by the fungal genus *Thyridium* Nitschke (1867). Robinson (1975) therefore replaced it with the name *Mitthyridium*. Although in leaf morphology resembling both *Syrrhopodon* and *Calymperes*, the creeping primary stems and broad, flat marginal border in the leaves easily differentiate *Mitthyridium*. The genus occurs throughout Malesia and Polynesia and extends to tropical Asia and northern Australia, with a single species in Africa. Most species are found in low-altitude oceanic habitats.

Reese and Stone (2012) included nine species for Australia, which we accept here, except that *Mitthyridium luteum* (Mitt.) H.Rob., replaces the name *M. papuanum* (Mitt.) Broth. for Australian material (see the discussion under *M. luteum*). Reese and Stone (2012) cautioned that some species are 'uncomfortably close to one another and difficult to circumscribe satisfactorily, but others are quite distinct', and decried the 'lack of sharp morphological discontinuities among the species' that made 'the taxa appear to blend almost imperceptibly with one another'. A detailed molecular study of this genus seems to be needed in order to more clearly delimit the species.

The following key, based on the key in Reese and Stone (2012), may be used to differentiate the Australian species.

Key to the species of *Mitthyridium* in Australia

1 Tips of at least some leaves tubular or funnel-shaped 2

1: Tips of leaves plane or with erect margins, or ± involute, not tubular or funnel-shaped 3

2 Tips of at least some leaves funnel-shaped, lacking a coarsely mammillose tubular portion; leaf border very broad at shoulders, mostly 100–150 µm wide. Gemmae often abundant, barely emergent beyond the funnel-shaped receptacle at the leaf tip ..... **M. constrictum**

2: Tips of at least some leaves tubular, the tubular portion often coarsely mammillose; leaf border narrow at shoulders, mostly 60–70 µm wide. Gemmae inconspicuous, emergent from tubular tips of gemmiferous leaves ..... **M. crassum**

3 Leaves with conspicuously flaring shoulders..... **M. fasciculatum**

3: Leaves mostly broadest at shoulders, mostly not conspicuously flared 4

4 Leaves mostly tightly crispate when dry; oblong, mostly less than 2 mm long; margins sharply toothed at shoulders and above, with spreading teeth ..... **M. repens**

4: Leaves variously contorted when dry but not crispate, lanceolate to linear, mostly more than 2 mm long; margins toothed or entire, if toothed, the teeth not spreading 5

5 Leaves long relative to width; limb of most leaves 2 or more times length of sheathing base 6

5: Leaves short relative to width; limb of most leaves only about 1–1.5 times length of sheathing base 8

6 Leaf margins entire, rarely weakly denticulate; limb ± involute ..... **M. leucoloma**

6: Leaf margins regularly denticulate to serrate; limb plane.....7

7 Leaf limb oblong-acuminate, tapering abruptly distally into an acute apex; most leaves about 0.5 mm wide at mid-limb, broadly linear, narrowed abruptly to an acute apex; border ending well below leaf apex; hyaline lamina reaching 1/4–1/2 leaf length, rounded to broadly acute distally, chlorophyllose lamina cells extending well down margin ..... **M. luteum**

7: Leaf limb long-acuminate, tapering gradually to an acute apex; most leaves about 0.25 mm wide at mid limb, narrowly linear to lanceolate-acuminate, tips gradually acuminate; border reaching almost to leaf apex; hyaline lamina short, 1/5 or less of leaf length, narrowly to broadly scalariform distally to ± truncate ..... **M. subluteum**

8 Leaves oblong-lanceolate, tapering above to a narrowly acute apex; apex narrow, slightly expanded at tip; margins serrate, at least in upper part; border ending about mid-leaf; hyaline lamina narrowly to broadly scalariform distally; gemmae borne adaxially on narrow tips of leaves ..... **M. perundulatum**

8: Leaves lingulate to lingulate-lanceolate, narrowing rather abruptly to an acute apex; margins ±entire to denticulate, entire in upper part; border ending well above mid-leaf; lamina cells smooth in lower part, papillose distally, small, upper lamina cells obscured by papillae; distal margins of hyaline lamina mostly broadly rounded; gemmae borne adaxially and abaxially on apex of costa ..... **M. flavum**

1. *Mitthyridium constrictum* (Sull.) H.Rob., *Phytologia* 32: 432 (1975). *Calymperes constrictum* Sull., *U.S. Expl. Exped., Musci* 17: 17, Pl. 3: a (1874).

Type citation: 'Hab. Sandwich Islands'.

Type: United States, Hawaii, s. loc., Sept 1840 – Apr 1841, *W. Sullivant s.n.*, as 'constricta'; lectotype (designated by Nowak 1980): FH, not seen; isolectotype: NY, not seen.

Illustration: Nowak (1980: 43).

Plants glossy yellowish-green above, rich brown in older parts, forming loose tangles, branches often considerably elongate, to 5 cm. Leaves mostly 2–3 mm long or slightly longer, 1.0–1.2 mm wide in the shoulder, oblong-acuminate, the tips constricted just below the flared funnel-shaped apex that forms the gemma receptacle; margins mostly denticulate; border very broad at base of chlorophyllose lamina, up to 130 µm wide at shoulders, narrowing towards the insertion and in the limb, disappearing below the flared leaf apex. Cells of leaf limb thick walled with corner thickenings and irregular, somewhat stellate lumina, pluripapillose throughout and strongly mammillate at leaf constriction, irregular in outline, c. 8–15(–18) µm long and wide; cells of expanded leaf apex smooth, with rounded to elongate-ovoid lumina. Hyaline lamina sharply defined but small for genus, margins broadly rounded to almost truncate distally, of 15–20 rows of cells. Costa smooth adaxially, ending at base of flared apex, abaxially scabrid with projecting mammillae. Gemmae often abundant, barely emergent to projecting beyond the funnel-shaped receptacle at the leaf tip, 230–400 µm in length. Sporophytes not seen in Australian material. (Fig. 1)

Diagnostic characters: Reese and Stone (2012) indicate that the gemmae are 'scarce, barely emergent'. In the specimen used for illustration there are abundant elongate gemmae that project clearly beyond the receptacle. Many or most leaves develop the flared funnel-shaped apex but may not produce gemmae. Brown rhizoids may also develop from the abaxial side of leaf tips.

With its characteristic leaf form, *M. constrictum* is easily distinguished. The leaves are tightly incurved and crisped when dry, superficially resembling *M. repens*. The straggly growth habit, highly modified leaf apex, broad leaf border and relatively narrow hyaline lamina region are useful guides for recognition.

Distribution: North-eastern Queensland between Mossman and Cardwell (Fig. 10.1). Also known from Cambodia, Malesia, Papua New Guinea, Philippines, French Polynesia, American Samoa, Oceania.

Habitat: Tree trunks and logs up to 1000 m in tropical rainforest.

Selected specimen seen: Queensland: Bellenden Ker, Goldsborough Track, 7 Sept 1987, *I.G. Stone 24574* (MEL 2326319).

Etymology: Latin *constrictum* (narrowed), referring to the constriction of the leaf below the apex.

Typification: The US Exploring Expedition, on which Sullivant made his Pacific collections, was in Hawaii from Sept 1840 to April 1841. Three specimens are listed on the HUH database (FH0060234, FH01146517 and FH01146518), all collected in the Sandwich Islands (Hawaii). Which of these is the lectotype is not known.

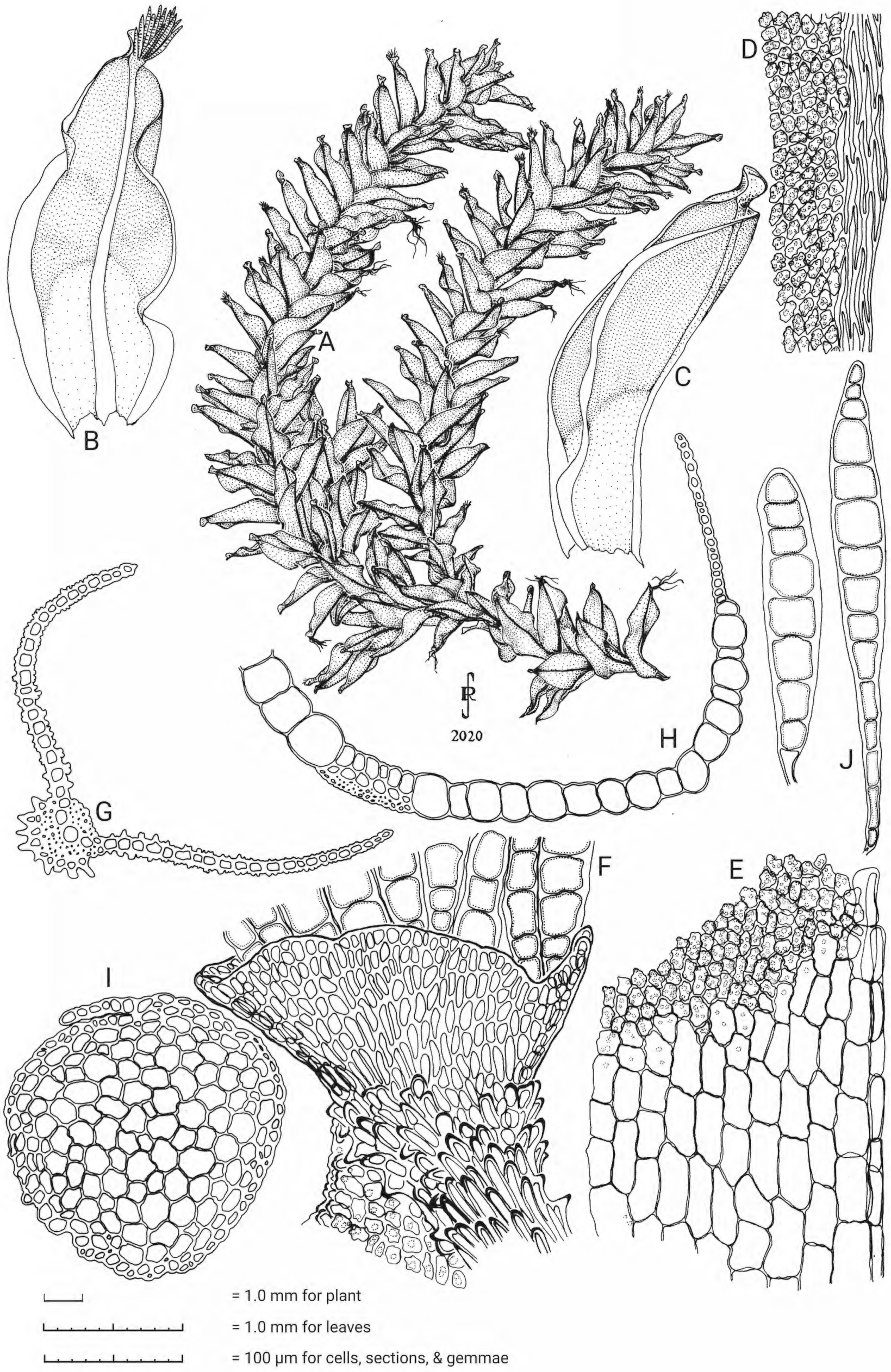

Fig. 1. *Mitthyridium constrictum* (Sull.) H.Rob. **A:** Habit of plants, drawn moist. **B, C:** Leaves with gemma receptacle and gemmae. **D:** Marginal cells of mid lamina. **E:** Cells of upper hyaline lamina region and lower chlorophyllous lamina. **F:** Detail of cells of gemma receptacle and abaxial surface of distal end of costa. **G:** Section of leaf lamina. **H:** Section of sheathing base of leaf. **I:** Stem section. **J:** Gemmae. Drawn from *I.G.Stone 24574*.

2. *Mitthyridium crassum* (Broth.) H.Rob., *Phytologia* 32: 432 (1975). *Syrrhopodon crassus* Broth., *Öfvers. Finska Vetensk.-Soc. Förh*. 40: 166. (1898).

Original material: 'Patria. British New Guinea, Milne Bay, in montibus prope Mita 2000' (W. Micholitz n 133)'.

Type: Papua New Guinea: Milne Bay, Feb. 1895, *W. Micholitz 133*; lectotype (designated by Nowak 1980): H-BR, not seen; isolectotypes: FH not seen, S not seen, W not seen, BM000662145!d.

Illustration: Nowak (1980: 53).

Plants small to medium sized, glossy, pale green, usually with short stems and branches, gregarious or in compact tufts. Leaves spreading when moist, variously contorted when dry, lanceolate-acuminate from a broadened base, 2–3 mm long, slightly undulate, ±plicate; leaf margins strongly inrolled towards the apex, weakly scabrid below apex; strongly bordered below, border narrowing upwards and disappearing well below the apex, weakly denticulate or almost entire, border 50–80 µm wide at shoulders. Cells of limb 5–10 µm long, 5–8 µm wide, thick walled, with irregular rounded to stellate lumina, smooth to weakly papillose except in tubular part of upper limb where often conspicuously papillose-bulging. Hyaline lamina broadly scalariform, reaching 1/4–1/3 leaf length, ending in a broad angle above, 14–20 cell rows wide. Gemmae inconspicuous, emergent from tubular tips of gemmiferous leaves, the cell walls very thick. Sporophytes not known. (Fig. 2)

Diagnostic characters: Reese *et al.* (1986a) included *M. crassum* in their descriptions of *Mitthyridium* species from the Huon Peninsula, Papua New Guinea, based on a report from Nowak (1980). They commented that the species is 'fairly distinct by its tubular and often conspicuously papillose leaf tips, broad border at the shoulders, and thick-walled cells', but noted the similarity of its leaves with those of *M. wallisii* (Müll.Hal.) H.Rob. 'under the microscope'. They further commented that the funnel-shaped leaf tips of *M. wallisii* are distinctive, and the tightly crispate dry leaves of the species distinguish it from the loosely contorted dry leaves of *M. crassum*, although they acknowledged that some specimens appear intermediate between the two species and suggested that they represent extremes of a single variable species. Menzel and Schultze-Motel (1990) treated *M. crassum* as a taxonomic variety of *M. wallisii*, a view not followed by Reese and Stone (2012). Illustrations in Eddy (1990) of leaves, leaf apices and cells of *M. wallisii* (p.148, fig. 260) and *M. crassum* (p.148. fig. 261) suggest that the leaves of the latter are longer, the limb is more tapered and less inrolled at the apex, and the lamina cells are less irregular in outline, but such differences are not unusual in any species of the genus. He later commented (p. 149) that 'some leaves [of *M. wallisii*] are scarcely different from those of *M. crassum*. Eddy (1990) stated that *M. wallisii* was distributed around the coasts of tropical Asia and Malesia and extended to northern Australia (although there are no herbarium records from Australia). We do not discount the possibility that the two species are conspecific, but prefer to maintain them as distinct species until this is demonstrated.

Reese (1997) described gemmae in the Calymperaceae. He noted that in gemmiferous leaves of *M. crassum,* most gemmae arise on the abaxial surface of the costa, outside the tubular tip, although a few gemmae may arise on the adaxial tip inside the tube, as in *M. constrictum*. The two species are easily separated by their gemmiferous leaf tips – tubular in *M. crassum*, funnel-shaped in *M. constrictum*.

Distribution: North-eastern Queensland from Mossman south to Tully (Fig. 10.2). Also known from Malesia, Philippines, New Guinea, American Samoa.

Habitat: Grows on trees, logs, rarely on rocks, usually below 600 m altitude.

Selected specimens seen: Queensland: Daintree National Park, Mossman Gorge, just east of Mossman, 8 June 1989, *W.D.Reese 17405* (MEL 2333052A); Daintree National Park, Mossman Gorge, 26 Aug 1999, *H.Streimann 64450* (CANB 607755.1).

Etymology: Latin *crassum* (thick), referring to the thick-walled cells of the upper leaf lamina. Nowak (1980) mistakenly attributed the name to the robust habit of the plant.

Typification: The collecting date is taken from an annotation on the isotype in BM. This specimen was annotated as an isolectotype by Nowak 'by my selection' in 1979, as above.

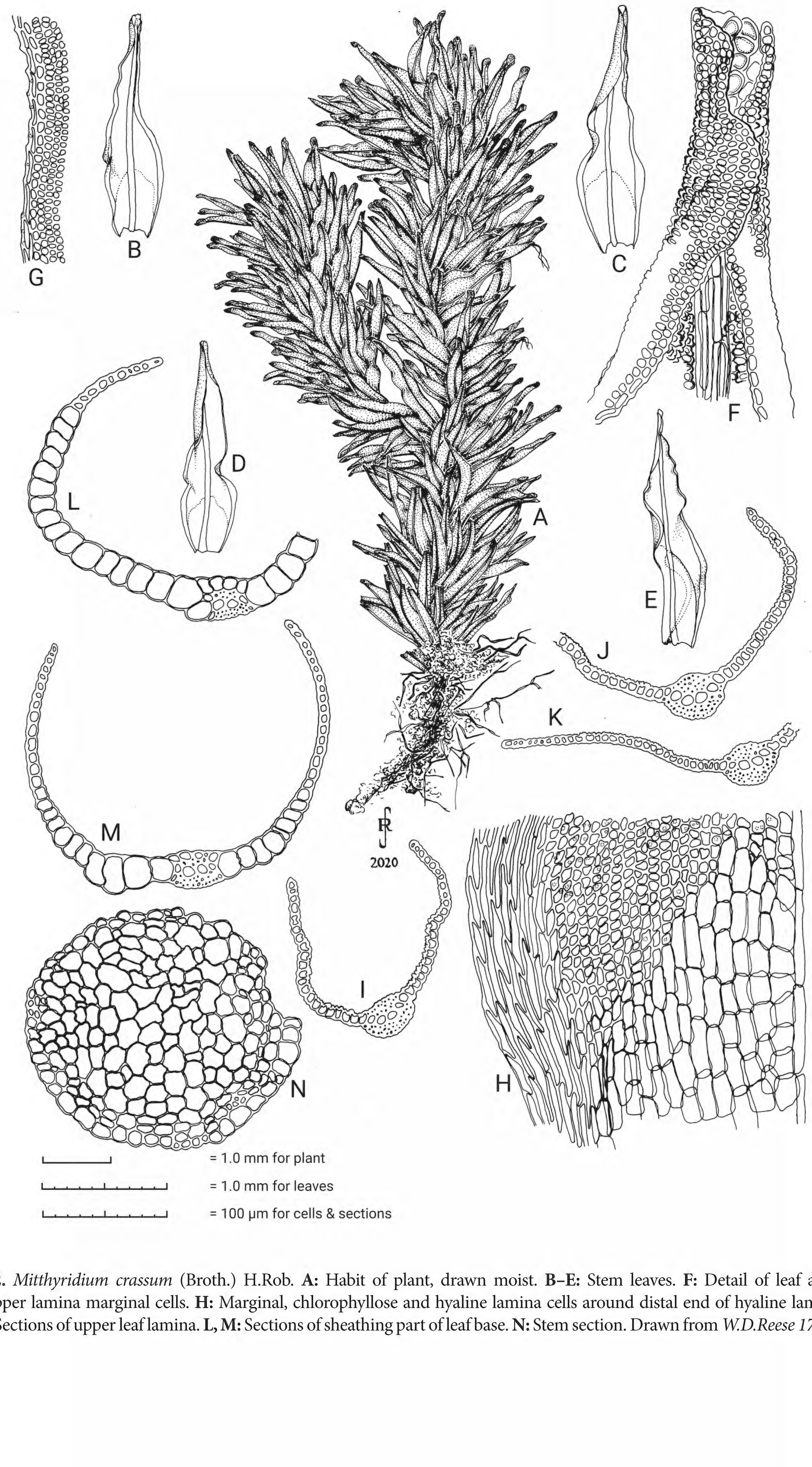

Fig. 2. *Mitthyridium crassum* (Broth.) H.Rob. **A:** Habit of plant, drawn moist. **B–E:** Stem leaves. **F:** Detail of leaf apex. **G:** Upper lamina marginal cells. **H:** Marginal, chlorophyllose and hyaline lamina cells around distal end of hyaline lamina. **I–K:** Sections of upper leaf lamina. **L, M:** Sections of sheathing part of leaf base. **N:** Stem section. Drawn from *W.D.Reese 17408*.

3. *Mitthyridium fasciculatum* (Hook. & Grev.) H.Rob., *Phytologia* 32: 433 (1975). *Syrrhopodon fasciculatus* Hook. & Grev., *Edinburgh J. Sci.* 3: 225. (1825).

Original material: 'Hab. Island of Ternate, Mr. Dickson. Sincapore, Dr Wallich.'

Type: Indonesia: Ternate, 1809, *D.Dickson s.n.* lectotype (designated by Menzel and Schultze-Motel 1990): BM-000662280!d; isolectotypes: E, FH, G, GL, NY.

Illustrations: Nowak (1980: 105, 107), Reese and Lin (1991: 369).

Plants robust for the genus, dull green to yellowish-brown; primary stems elongate, to 10 cm long, branches elongate ascending, to 4 cm long. Leaves 3–4 mm long, 1.0–1.3 mm wide, patent when moist, ±erect when dry and the limb somewhat curved; base suberect sheathing, strongly flared at shoulders, the limb triangular lanceolate tapering to an acute or subacute serrulate apex; lamina irregularly flexuose or undulate; border broad at shoulders, 80–110 μm wide, composed of 12–20 rows of narrow thick-walled cells, gradually narrowing upwards and disappearing shortly below leaf apex. Cells of limb thick-walled, irregularly quadrate to oval-rectangular, to c. 6 μm wide, minutely pluripapillose on both surfaces partially obscuring the cells. Hyaline lamina reaching 1/4–1/3 leaf length, broadly truncate distally; chlorophyllose lamina not or scarcely decurrent down margins inside border. Gemmae rare, sparse, pale, warty, fusiform, arising adaxially and abaxially on leaf tips (Eddy 1990, notes gemmae usually abundantly produced from unmodified leaves). Sporophytes not found in Australian material. Eddy (1990) stated: 'Fruit frequent; seta 6–12 mm long; capsule cylindrical.' (Fig. 3)

Diagnostic characters: The species is readily distinguished by its large size, dull aspect and sprawling habit. The leaves have serrulate margins which, together with the conspicuously flared shoulders, wide borders and truncate hyaline lamina, are distinctive under the microscope. *Mitthyridium luteum* may be equally coarse but the hyaline lamina is relatively shorter and the leaf shoulders less obviously flared.

Reese and Lin (1991) described the gemmae as frequent but inconspicuous in specimens from China, and did not find sporophytes. In Australian collections we have seen, sporophytes are common and gemmae are scarce. *Mitthyridium fasciculatum* is the only Australian species of to produce gemmae from the tips of short, linear stacks of cells known as gemmipars (Reese 2001).

Distribution: Common and conspicuous in eastern Queensland, from the Iron Range as far south as Fraser Island (Fig. 10.3). A widespread eastern palaeotropical species also known from Madagascar, Mauritius and Seychelles, south east Asia, China (Hainan), Thailand, Malesia, Philippines, Papua New Guinea, Fiji, Western Samoa.

Habitat: Trees, logs and rocks in wet forest and rainforest to about 1000 m elevation.

Selected specimens seen: Queensland: Fishery Creek on slopes of Mt Bellenden Ker, near Gordonvale, epiphyte on trees near weir, 3 Oct 2004, *A.Cairns & D.Meagher B-327* (BRI AQ649271); Mossman Gorge, Daintree National Park, epiphyte in lowland riparian rainforest, 13 May 2013, *D.A.Meagher & A.Cairns WT-184* (BRI AQ1016931); Cedar Bay Road, north of Bloomfield River, 6 Aug 1979, *I.G.Stone 15827* (BRI AQ0874603).

Etymology: Latin *fasciculatum* (a small bundle), referring to the long, clustered branches.

Typification: The island of Ternate is in the Indonesian Maluku Islands (Moluccas). One sheet in E (E00011728/29/30) contains three sets of specimens (labelled in pencil A, B and C, equating to 28/29/30), with a stamp 'Greville herb.' and in ink 'Ternate New Zealand Dickson' and 'Menzies herb', presumably merely a mislabelling.

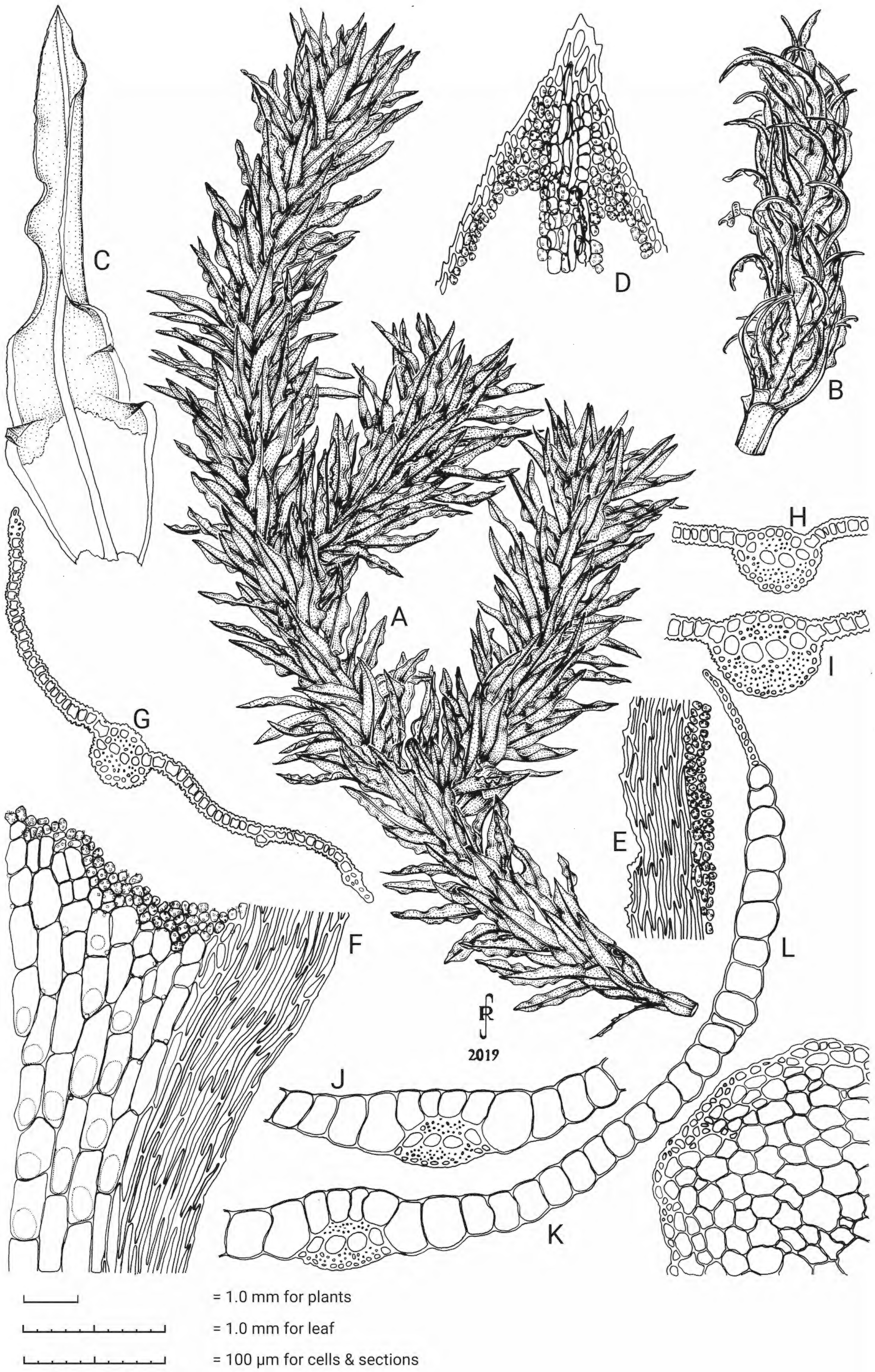

Fig. 3. *Mitthyridium fasciculatum* (Hook. & Grev.) H.Rob. **A:** Habit of plant, drawn moist. **B:** Branch, drawn dry. **C:** Stem leaf. **D:** Cells of leaf apex, adaxial view. **E:** Lower mid-lamina marginal cells. **F:** Cells of shoulder region of leaf. **G:** Section of upper limb of leaf. **H, I:** Costal sections from mid-limb. **J, K:** Sections of sheathing base of leaf. **L:** Part stem section. Drawn from *I.G.Stone 15827*.

4. *Mitthyridium flavum* (Müll.Hal.) H.Rob., *Phytologia* 32: 433 (1975). *Syrrhopodon flavus* Müll.Hal., *Bot. Zeitung* (*Berlin*) 13: 763. (1855).

Original material: 'Patria. Java: inter alios muscos specimina pauca manca inveni.'

Type: Indonesia: Java, *s.d.* [before 1855], *s.coll.* holotype: B (presumably destroyed).

Illustrations: Reese *et al.* (1986b: 50), Reese and Lin (1991: 371), Ellis (2015: 337, Fig. 1).

Plants small, green to yellowish green, forming low-growing thin, straggling (occasionally dense) mats; branches mostly short, less than 1 cm long, occasionally longer, often hook-shaped at the tips; rhizoids glossy reddish-brown, arising from under side of stems, occasionally also from leaf tips. Leaves 1.5–3.0 mm long, c. 0.6 mm wide at shoulders, lingulate to lingulate-lanceolate, not or only slightly broader at shoulders, narrowing rather abruptly towards an acute apex; lamina gently undulate; margins ±entire to denticulate, entire in upper part; border at shoulders 30–50 μm wide, narrowing upwards, disappearing well below apex, sometimes not much above mid leaf. Lamina cells smooth in lower part, papillose distally, small, 5–7 μm wide, upper lamina cells obscured by papillae; hyaline lamina reaching 1/4–1/3 leaf length, margins typically broadly rounded to acutely angled upwards to costa, cells in 15–20 rows. Costa smooth, ending shortly below leaf apex. Gemmae pale, ±warty, borne both adaxially and abaxially on apex of costa. Sporophytes not seen in Australian collections; in Malesian specimens with a seta 3–8 mm long, capsule typical of the genus. (Fig. 4)

Diagnostic characters: *Mitthyridium flavum* is quite common and often abundant in northern Queensland. The straggly habit, short branches, and the broad, short, oblong or somewhat acuminate and abruptly pointed leaves are distinctive. The species may be mistaken for *M. perundulatum* having short, broad leaves, but the leaf margins there are undulate and sharply toothed above and most leaves are narrowly acuminate, not abruptly pointed as in *M. flavum*. *Mitthyridium luteum* also has abruptly short-pointed leaves but they are usually much larger, 3–4 mm long and with margins denticulate almost to the leaf tip, and the cells of the leaf limb are smooth or minutely papillose. Branches of *M. flavum* are mostly short while those of *M. luteum* are often elongate.

Eddy (1990) noted that sporophytes were common in Malesia. However, none have been found in Australian collections.

Distribution: Known from Melville Island, Northern Territory and north-eastern Queensland as far south as Finch Hatton Gorge, inland of Mackay (Fig. 10.4). Widely distributed and frequent throughout tropical Africa, Asia; Sri Lanka, Cambodia, China (Hainan, Yunnan), scattered through lowland Malesia, especially coastal regions, Philippines, Papua New Guinea.

Habitat: Epiphytic on tree trunks, palm trunks and vines in lowland rainforest (including *Licuala* rainforest), on shoreline trees and mangroves, and occasionally on rotting logs, to 500 m elevation.

Selected specimens seen: Queensland: Bramston Beach, near Babinda, 7 Nov 2014, *A.J.Franks AJF1411006A* (BRI AQ0910194); Cape Tribulation Road, c. 4 miles north of Daintree River Ferry, 22 May 1974, *D.H.Norris 42685* (BRI AQ0760391).

Etymology: Latin *flavum* (golden or reddish yellow), referring to the overall colour of the type specimen in the dried state.

Typification: Because the protologue states this species was described on the basis of a small specimen [*specimina pauca manca*, all having singular endings suggest a single find of a few shoots only] found among other mosses, it seems likely that an isotype does not exist. If no original material can be found a neotype would need to be selected.

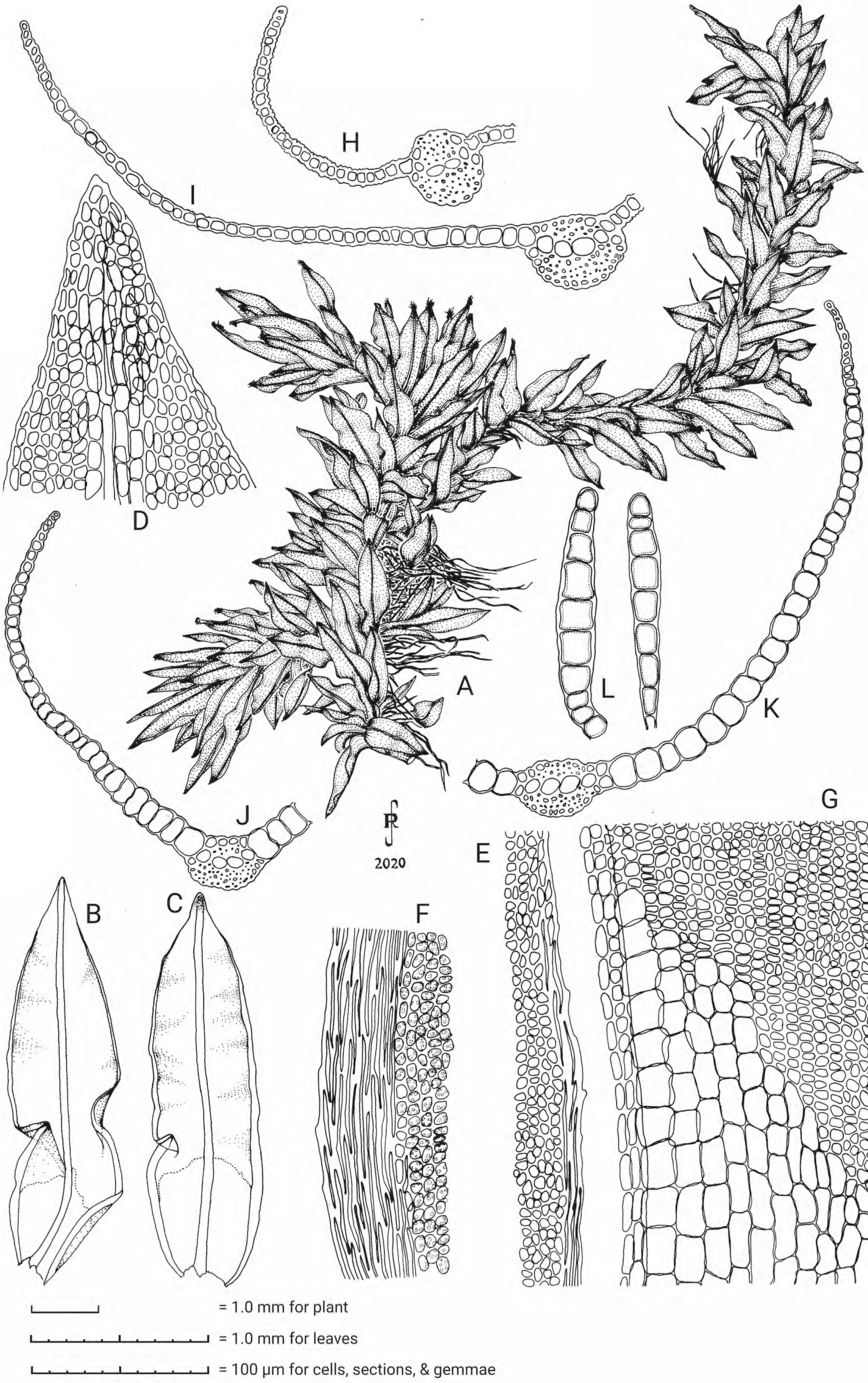

Fig. 4. *Mitthyridium flavum* (Müll.Hal.) H.Rob. **A:** Habit of plant, drawn moist. **B, C:** Stem leaves. **D:** Cells of leaf apex. **E:** Marginal cells near leaf apex (papillae omitted for clarity). **F:** Marginal cells of lower mid-lamina. **G:** Cells of upper end of hyaline lamina. **H, I:** Sections of upper and middle leaf lamina. **J, K:** Sections of leaf sheathing base. **L:** Gemmae. Drawn from *D.H.Norris 42685*.

5. *Mitthyridium leucoloma* (Müll.Hal.) H.Rob., *Phytologia* 32: 433 (1975). *Syrrhopodon leucoloma* Müll.Hal., *Bot. Jahrb. Syst.* 5: 86. (1883).

Original material: None cited.

Type: Papua New Guinea: *s.d.* [August 1875, see note below], *F.Naumann s.n.* holotype: B (presumed destroyed); lectotype (designated here): BM000662463!d.

Illustration: Nowak (1980: 82).

Plants robust, green, yellowish-green to yellow-brown, somewhat glossy, forming loose soft tangled mats; stems and branches elongate, up to 5 cm long. Leaves mostly to 4.0 mm long, moderately flared at shoulders; stiff when moist, recurved-spreading, when dry incurved but not strongly contorted; limb involute wet or dry, weakly undulate; margins entire, except at extreme apex, rarely with weak denticulations; border 60–70 μm at shoulders, with 8–11 rows of cells, narrowing upwards and disappearing below the apex. Cells of limb smooth to finely papillose, upper lamina cells small, 5–6 μm wide. Hyaline lamina reaching 1/4–1/3 leaf length, cells in 20–30 rows, distal margins arched, irregular in outline, upper cells of hyaline lamina commonly interdigitising with chlorophyllose cells of limb, the chlorophyllose lamina cells decurrent down margins and costa. Costa strong, often reddish. Gemmae sparse, pale green to brownish, borne adaxially and abaxially on costa at leaf tip. Sporophytes frequent. Calyptra c. 3 mm long. Seta 5–6 mm long, red. Capsule exserted, 1.5–2.0 mm long. Operculum 1.0–1.5 mm long. Peristome teeth reddish-yellow, slender, c. 300 μm tall, papillose, with transverse sutures. Spores 15–21 μm in diameter, papillose. (Fig. 5)

Diagnostic characters: *Mitthyridium leucoloma* resembles *M. fasciculatum*, but its glossy appearance, entire leaf margins and lack of flaring shoulders are diagnostic. Eddy (1990) also regarded *M. leucoloma* as similar in habit to *M. luteum* but noted that 'it differs in its rigid leaves, broader leaf tip and stout costa', describing the costa, as in Australian specimens, as 'strong, often reddish'. It was treated by Reese *et al.* (1986 a, b) as a synonym of *M. obtusifolium* (Lindb.) H.Rob., but later regarded as a distinct species following Nowak (1980) and Eddy (1990). Eddy (1990) noted that *M. leucoloma* was almost endemic to Malesia, with its main occurrence in New Guinea and neighbouring islands. Nowak (1980) extended the range northwards to the Philippines and the Australian collections have extended the species range further to the south east.

Distribution: Occurs in far north Queensland from Torres Strait to Conway Range, east of Proserpine (Fig. 10.5). Known elsewhere from the Philippines, Malesia, Papua New Guinea, New Britain.

Habitat: Epiphytic on tree and palm trunks and on fallen timber in lowland rainforest and mangroves.

Selected specimen seen: Queensland: Cairns Botanic Gardens, 26 Aug 1989, *I.G.Stone 25399* (BRI AQ0760393).

Etymology: Greek *leukos* (white) + *loma* (border), referring to the pale border of elongate cells on the margins of the leaves.

Typification: The original publication was titled 'Die auf der Expedition S.M.S. Gazelle von Dr. Naumann gesammelten Laubmoose' and the species was published in section 3 ('Nova Guinea'). BM000662463 was collected by Friedrich Naumann in 1875 and is annotated in script '*Syrrhopodon leucoloma* C. Müll. Insulae inter Novam Guineam & [?Talvate Boyma], Sept 1875 Dr. F. Naumann', and is also annotated 'isotype' by Bill Reese, although no holotype has been discovered. Regardless, there is no doubt that this is original material. Since no specimen traceable to the Berlin herbarium (where Müller's herbarium was kept) has surfaced since its almost complete destruction in 1943, we consider it appropriate to designate BM000662463 as lectotype.

A chart in the account of the route of the voyage (Anonymous 1889: foldout facing page 252) shows that the *Gazelle* left Bougainville Island (now part of Papua New Guinea) on 28 August 1875 and sailed south and then west in the Solomon Sea before turning south for Australia, making no landfall before arriving at Brisbane on 29 September. The date on the lectotype therefore must be incorrect. The type locality would have to be New Hanover (Lavongai), New Ireland (Latangai), New Britain or Bougainville Island, the only landfalls made by the *Gazelle* between clearing the Galewo Straits at the western end of New Guinea on 25 June and arriving at Brisbane (Anonymous 1889: foldout facing page 160). All these islands are in Papua New Guinea.

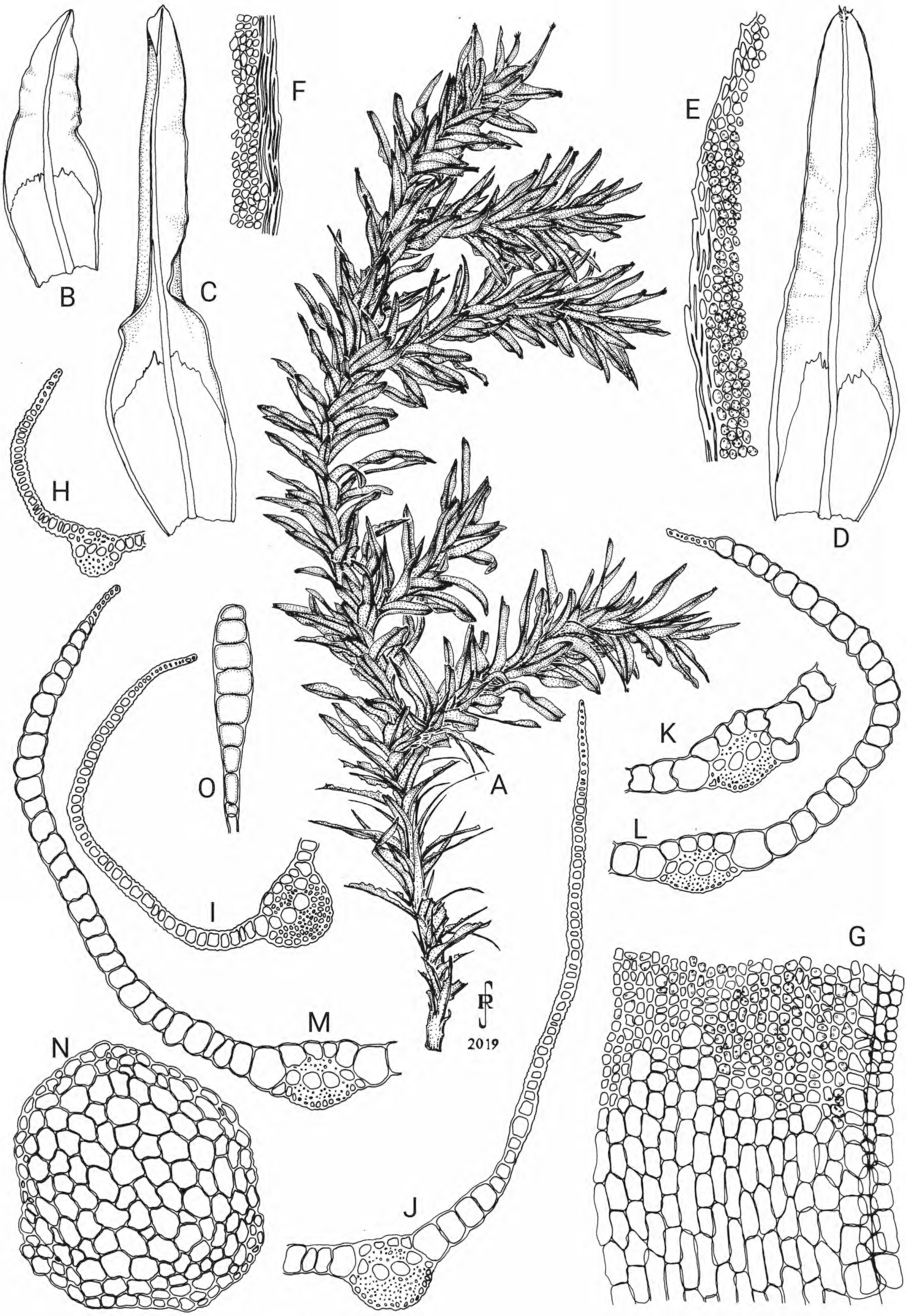

Fig. 5. *Mitthyridium leucoloma* (Müll.Hal.) H.Rob. **A:** Habit of plant, drawn moist. **B–D:** Leaves. **E:** Marginal cells from just below leaf apex. **F:** Mid lamina marginal cells (papillae omitted for clarity). **G:** Cells from distal end of hyaline lamina. **H, I:** Sections of leaf limb. **J:** Sections of leaf shoulder region. **K–M:** Sections of sheathing leaf base. **N:** Stem section. **O:** Gemma. Drawn from *I.G.Stone 25399*.

6. *Mitthyridium luteum* (Mitt.) H.Rob., *Phytologia* 32: 433 (1975). *Thyridium luteum* Mitt., *J. Linn. Soc. Bot.* 10: 188 (1868).

Original material: 'Hab. Tutuila. No. 106. Ovalan [= Ovalau], Figi Islands, on stones in the mountains, Milne.'

Type: Fiji: Ovalau ('Ovalan'), *s.d.* [1852–1853], *Milne 106.* lectotype (designated by Nowak 1980): BM000662425!d; isolectotype: NY01127905!d. Residual syntype: American Samoa: Tutuila, *s.d.* [10–24 Oct 1849], *T.Powell 106*. syn: BM000662460!d, NY01127901!d.

Syrrhopodon papuanus Broth., *Öfvers. Finska Vetensk.-Soc. Förh.* 37: 156 (1895); *Thyridium papuanum* (Broth.) Fleisch., *Musci Fl. Buitenzorg* 1: 232 (1904); *Mitthyridium papuanum* (Broth.) H.Rob., *Phytologia* 32: 434 (1975).

Original material: 'Patria. New Ireland, umbi anno 1893 detexit W. Micholitz.'

Type: New Ireland, Oct 1893, *W. Micholitz* [*94*] Lectotype (designated by Nowak 1980): BM, not seen.

Illustrations: Nowak (1980: 138; also page 131 as *M. papuanum*).

Plants robust, in loose soft tangled mats, yellowish-green, somewhat glossy, profusely branched; branches short or long, often curved near tips. Leaves mostly 3–4 mm long, broadly linear from a scarcely broadened base, broadly acuminate, narrowed abruptly to an acute apex; spreading when moist, incurved with inrolled margins when dry, margins denticulate almost to leaf tip; border 30–40 μm wide at shoulders, of 4–8 rows of hyaline cells, narrowing above and disappearing well below leaf apex; cells of limb small, 5–8 μm wide, smooth to minutely papillose. Hyaline lamina short, reaching 1/4–1/2 leaf length, of 20–30 rows of cells, demarcation rounded to broadly acute, chlorophyllose lamina cells extending well down margin. Gemma clavate, infrequent, arising adaxially and abaxially on costa from a small area just below apex. Sporophytes not seen in Australian material. (Fig. 6)

Etymology: Latin *luteum* (yellow), presumably referring to the overall colour of the dried type specimen.

Distribution: Rather rare in north-eastern Queensland, from Cape Tribulation as far south as Tully (Fig. 10.6). Elsewhere known in Malesia from Java, West Irian, Borneo, Papua New Guinea; Philippines; and in Oceania from Fiji, Samoa, Tahiti, Society Islands, Solomon Islands.

Habitat: Tree trunks, branches and twigs, and occasionally on soil, in rainforest from near sea level to 900 m.

Diagnostic characters: The description above is based on Australian material which Reese and Stone (2012) considered to belong to *Mitthyridium papuanum*. Nowak (1980) stated that *M. papuanum* is closely related to *M. luteum* as both have similar tapered leaf tips, although she considered *Mitthyridium papuanum* (Broth.) H.Rob. to be a separate species, based on small differences in the ratio of leaf length to width, the width of the hyaline leaf margin, and the lengths of the operculum, inner peristome teeth, operculum beak and seta. The gametophytic differences are very minor and could easily be accounted for by the inherent variability of *M. luteum* noted by Eddy (1990, p.140). Nowak (1980) stated that the operculum in *M. papuanum* is significantly shorter than that of *M. luteum*, although her illustrations of the species (on pages 131 and 138) show an operculum of similar length. Similarly, she stated that the seta in *M. papuanum* was up to three times longer than the seta in *M. luteum*, although her illustrations show setae of similar lengths. Reese *et al.* (1986a,b) placed *M. papuanum* in synonymy with *M. luteum*, as did Eddy (1990). Although they were treated as separate species by Reese and Stone (2012), we cannot see that there is sufficient evidence to justify this, and treat them here as conspecific.

Eddy (1990) noted that the coarse/robust habit of *M. luteum* may result in misidentification with *M. fasciculatum*. However, he noted that 'the latter has more pronounced shoulders and cancellinae [hyaline lamina] which occupy a greater proportion of the leaf, as well as a costa that is decidedly roughened in the upper limb'. A 'roughened costa' is not included in Eddy's (1990) description of *M. fasciculatum*, although illustrations of the leaf sections (Eddy 1990, Fig. 251 K, p.136) clearly show this. Australian specimens of *M. fasciculatum* examined and illustrated here (see *M. fasciculatum* Fig. 3 G) have a smoother costa than their Malesian counterparts, not dissimilar to that of *M. luteum* (Fig. 6 J, K). *Mitthyridium leucoloma* also resembles *M. luteum* in its robust habit; see under that species for differences.

Selected specimens seen: Queensland: JCU Canopy Research Facility site, near Thompson Creek, Daintree to Bloomfield Road, 44 km NNE Mossman, 26 Aug 1999, *A.Cairns B-191* (BRI); Creek along Ella Bay Road, c. 3 km from Flying Fish Point, 31 Oct 2014, *A.J.Franks AJF1410016* (BRI AQ0910081).

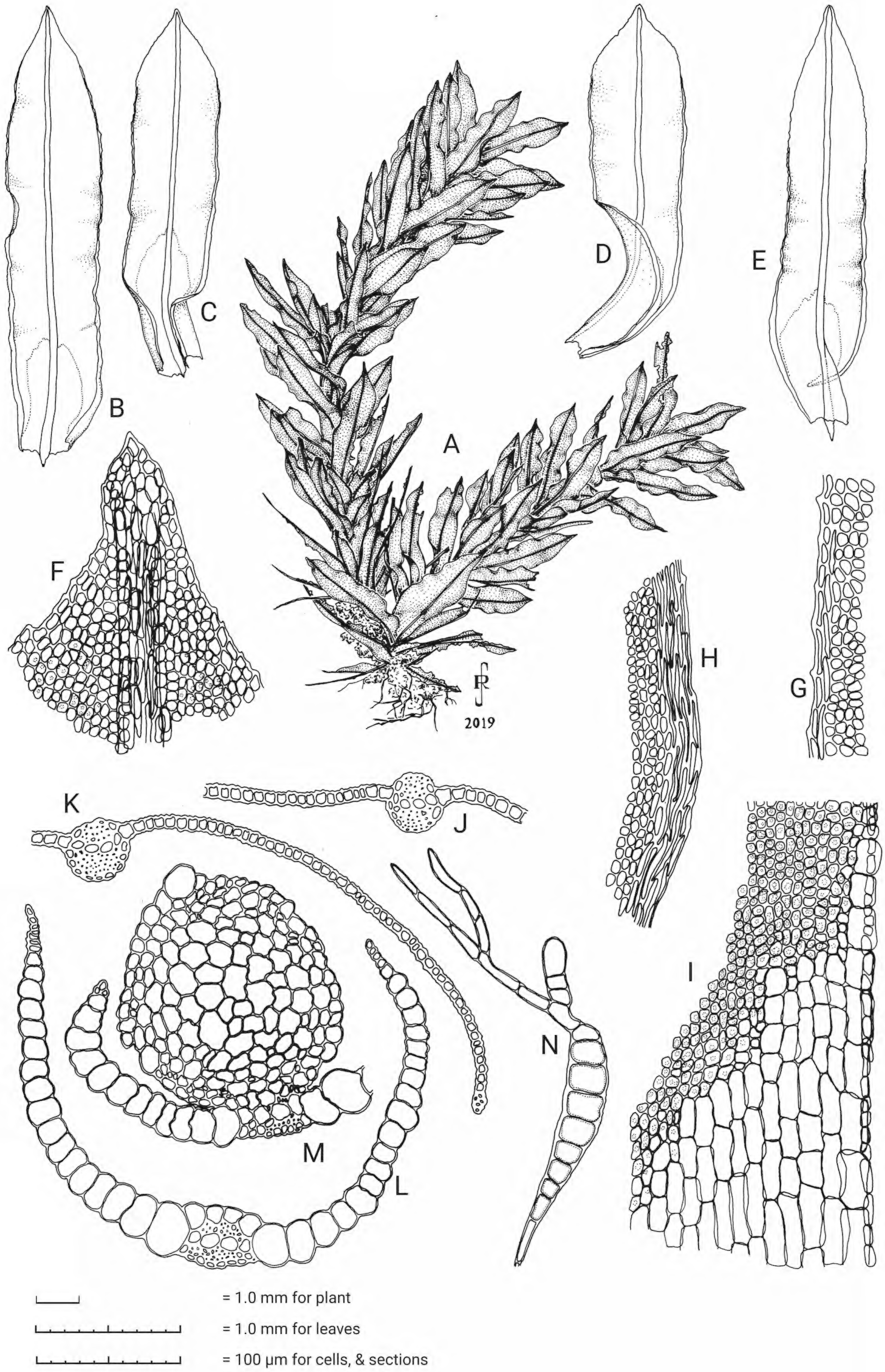

Fig. 6. *Mitthyridium luteum* (Mitt.) H.Rob. **A:** Habit of plant, drawn moist. **B–E:** Leaves. **F:** Cells of leaf apex, abaxial view. **G:** Cells of mid limb margin. **H:** Cells of leaf margin in shoulder region. **I:** Cells of distal hyaline lamina. **J, K:** Sections of costa and leaf limb. **L:** Section through hyaline lamina. **M:** Stem section. **N:** Germinating gemma. Drawn from *A.J.Franks AJF1410016*.

7. *Mitthyridium perundulatum* (Broth.) H.Rob., *Phytologia* 32: 434 (1975). *Syrrhopodon perundulatus* Broth., *Fl. Schutzgeb. Südsee* 83 (1900).

Original material: 'Kaiser Wilhelmsland: Wald am Gogol-Mittellauf, an Baumrinde (Lauterbarch n.970[b]), Milne-Bai, im Gebirge bei Mita 200 m, an Baumzweigen (Micholitz n. 134).'

Type: Papua New Guinea: forest near Gogol River, *s.d.* [1889–1900], *C.A.Lauterbach 970b.* lectotype (designated by Nowak 1980: 151: BM000662171!d. Residual syntypes: Milne Bay, Feb 1895, *W.Micholitz 134.* syn: PC-0100853!d, PC0100854!d, BM000662225!d.

Illustrations: Dozy and Molkenboer (1856: 57, as *Syrrhopodon jungquilianus*), Reese and Stone (1995: 21).

Plants small to medium sized, green or yellowish-green; stems relatively short, to 5–6 cm, branches to 1.5 cm long, in compact sods or tufts. Leaves oblong-lanceolate, mostly 2.0–2.5 mm long, tapering above to a narrowly acute apex; apex narrow, slightly expanded at tip, commonly consisting of costa and narrow wings of a few lamina cells; leaf margins serrate, at least distally; cells of limb smooth to minutely papillose; border in shoulder region 10–12 cells wide, narrowing upwards and disappearing about mid leaf; hyaline lamina very short, reaching 1/4–1/3 leaf length, narrowly to broadly scalariform distally, acutely angled to costa. Gemmae frequent, usually inconspicuous, adaxial on narrow tips of leaves. Sporophytes not seen in Australian material. (Fig. 7)

Diagnostic characters: *Mitthyridium perundulatum* could be confused with *M. flavum*, but the leaves of *M. flavum* are broader, shorter, oblong or somewhat acuminate and abruptly pointed. The leaves of *M. luteum* (as *M. papuanum* in Reese and Stone 2012) may be abruptly short-pointed but are usually much longer, 3–4 mm long and denticulate almost to the leaf tips. Akiyama and Reese (1993) noted that the species was 'like a miniature version of *M. undulatum*' (not recorded from Australia) but in that species the leaves are broadly acuminate and the border of hyaline cells extends nearly to the leaf tip. *Mitthyridium perundulatum* is also similar to *M. jungquilianum* (Mitt.) H.Rob., but there the leaves are linear to linear-lanceolate from a broader base, broadly toothed where bordered, the lamina cells smooth to finely papillose adaxially and abaxially, and the distal margins of the hyaline lamina rounded to obliquely truncate. Reese *et al.* (1986b) treated *M. perundulatum* as a synonym of *M. jungquilianum*. *Mitthyridium jungquilianum* is also similar to *M. flavum* and *M. subluteum*, although, as Reese *et al.* (1986b) pointed out, there are significant differences between the species. Nevertheless, they noted that some Malaysian specimens they examined seemed to grade towards *M. flavum* or *M. subluteum*. Reese and Stone (2012) retained *M. perundulatum*, noting that Australian specimens of this species had been previously misidentified as *M. jungqulianum* and *M. undulatum* (neither of which has been recorded from Australia). See also discussion under *M. subluteum*.

Distribution: Occurs in north-eastern Queensland from Cape Tribulation to Cardwell (Fig. 10.7). Also known from Malesia, North Borneo, Moluccas, Papua New Guinea.

Habitat: Epiphytic on trees and vines in rainforest, mostly at low elevations but occasionally higher, up to 400 m.

Etymology: Latin *per–* (very) + *undulatum* (undulate), referring to the crispate leaves when dry.

Selected specimen seen: Queensland: Graham Range communication towers access road, Bramston Beach, 7 Nov 2014, *A.J.Franks AJF1411006C* (BRI AQ0910193).

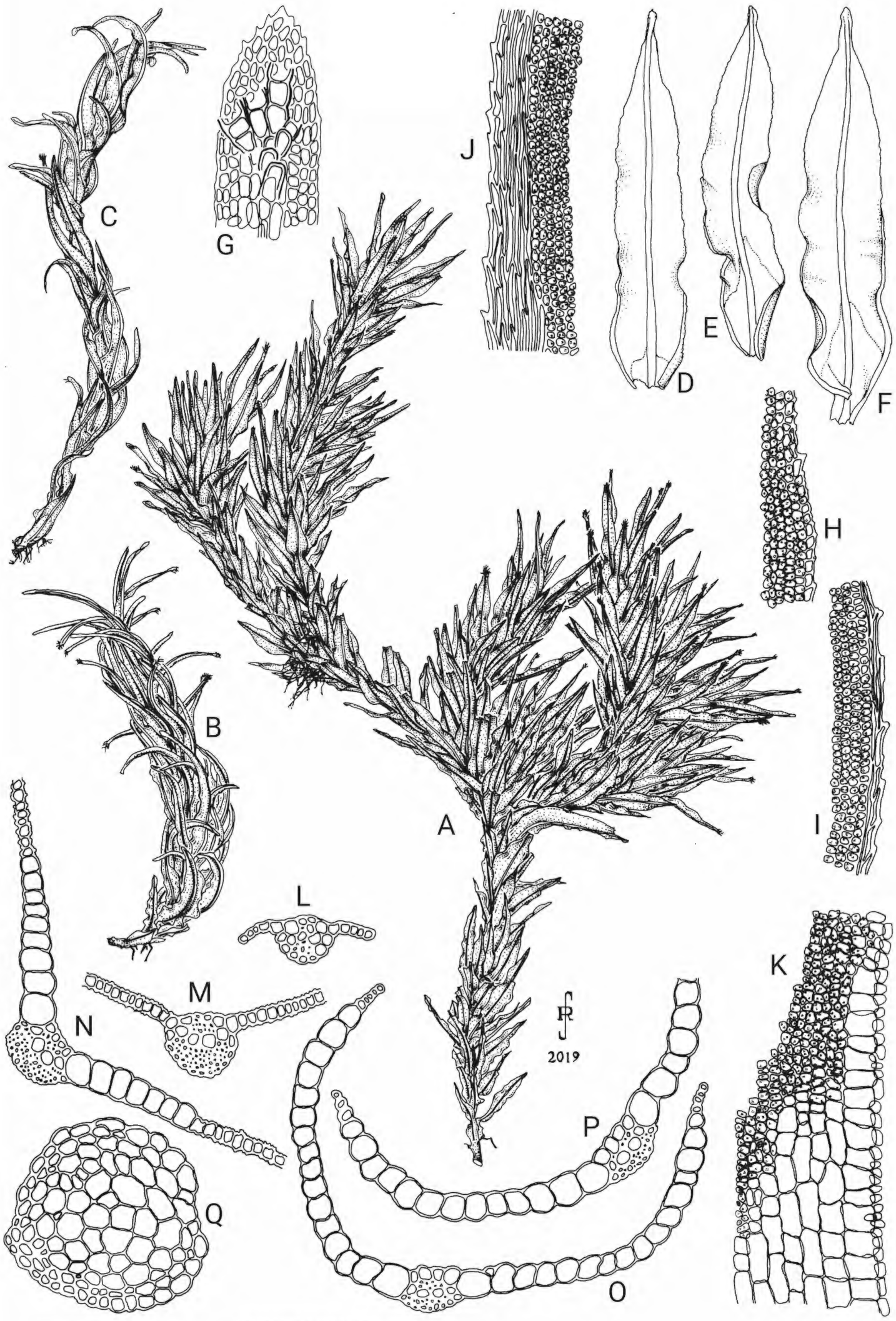

Fig. 7. *Mitthyridium perundulatum* (Broth.) H.Rob. **A:** Habit of plant, drawn moist. **B, C:** Branches, drawn dry. **D–F:** Leaves. **G:** Cells of leaf apex, adaxial view. **H:** Cells of upper lamina margin. **I:** Cells of mid lamina margin. **J:** Marginal cells at level of distal end of hyaline lamina. **K:** Cells of the distal end of hyaline lamina. **L:** Section of leaf apex showing costa and narrow lamina wings. **M:** Section of mid leaf limb. **N–P:** Sections of sheathing base of leaf. **Q:** Stem section. Drawn from *A.J.Franks AJF1411006C.*

8. *Mitthyridium repens* (Harv.) H.Rob., *Phytologia* 32: 434 (1975). *Syrrhopodon repens* Harv. in Hook., *Icon. Pl. Rar.* 1: 22. (1836).

Original material: None cited

Type: Malaysia, Penang, *s.d., Wallich s.n.* holotype: BM000676840!d.

Syrrhopodon undulatus Broth. & Geh., *Öfvers. Finska Vet.-Soc. Förhandl.* 42: 96 (1900), *nom. illeg.*, *non S. undulatus* Müll.Hal., *Bot. Zeitung* (*Berlin*) 2: 727 (1844).

Original material: 'Patria. Queensland, Bellenden Ker Range (Mrs Gribble in herb. Melbourne).'

Type: Australia: Queensland: Bellenden Ker Range, *E.Gribble s.n.* holotype ?MEL-2146712B, not seen; isotype: ?H-BR.

Illustrations: Nowak (1980: 97, 169, 199, 201 as *M. louisiadum*), Reese *et al.* (1986b: 51), Ellis and Tan (1999: 28).

Plants small and compact, forming dense mats or low turfs, yellowish-green; branches short, densely foliate, 5–6 mm tall, rarely more. Leaves lingulate with pronounced shoulders, 1–2 mm long, c. 0.5 mm wide, spreading when moist, tightly crisped when dry; margins broadly bordered below, 10–12 rows of elongate thick-walled cells at shoulders, border narrowing above and ending below apex; margins conspicuously dentate; apex broad, rounded-obtuse and apiculate. Lamina cells small, 5–6 μm wide, thick-walled with irregular rounded lumina, finely papillose, cells obscured by papillae. Hyaline lamina reaching 1/4–1/3 leaf length, rounded to ±transverse above, with lamina cells decurrent down margins and against costa. Gemmae sparse but usually present, arising from both surfaces of tip of costa of unmodified leaves, inconspicuous, green, 100–150 μm long. Sporophytes apparently uncommon. Calyptra 1.0–1.5 mm long. Seta reddish, 3–5 mm long. Capsule exserted, 1.0–1.5 mm long; operculum c. 1 mm long, falling with calyptra. Peristome teeth yellowish, c. 160 μm tall, transversely barred, slightly papillose. Spores 15–18 μm in diameter. (Fig 8)

Diagnostic characters: Reese (1994) stated that *M. repens* 'includes populations of plants that range from very small to rather large, yet otherwise in agreement with one another.' However, in Australia this is one of the most distinctive species of the genus, recognisable by its small stature, short oblong leaves that are crispate when dry, and leaves having a broad border and the margins having sharp, spreading teeth. It is similar in size to *M. flavum*, but more compact. The broader lower leaf border with coarse serrations is diagnostic.

Distribution: North-eastern Queensland, from Torres Strait to Ingham (Fig. 10.8). Also known in tropical Asia from Sri Lanka, Andaman Islands, Myanmar, Thailand, Philippines, Malesia, Papua New Guinea, Fiji.

Habitat: Grows on trees, vines, shrubs, stumps, dead wood and rock in rather open forest, mostly at or near sea level but ranging up to 500 m elevation.

Etymology: Latin *repens* (creeping), referring to the creeping, prostrate habit.

Selected specimens seen: Queensland: The Boulders, 'Wonga Walk', 6 km W of Babinda, 25 Aug 1999, *H.Streimann 64400* (CANB 607704.1); Emmagen Creek crossing, Cape Tribulation Road, Daintree National Park, 11 May 2013, *D.A.Meagher & A.Cairns WT-159* (BRI AQ1016931); Heathlands Resource Reserve, Captain Billy track, 13 Mar 2017, *S.L.Thomson, B.Anau et al. SLT 17015* (BRI AQ1019729).

Typification: Long (1995) provided a detailed account of taxa published by Harvey (1836) in J.D. Hooker's *Icones Plantarum*, which were validly published by William Harvey as illustrations accompanied by short captions. Full descriptions, apparently prepared at the same time by Harvey (Long 1995: 6), were subsequently published in Harvey and Hooker (1840). On page 8 of Harvey and Hooker's volume, the locality for the specimen of *Syrrhopodon repens* illustrated by Harvey (1836: t. XXII) was given as 'Hab. Penang; on the bark of trees, over which it creeps in wide patches'. The collector was noted as Nathaniel Wallich (Harvey and Hooker 1840: 1), who visited Penang in 1822 (Long 1995: 3). Harvey had worked on Wallich's moss collections between April 1934 and July 1835 (Long 1995: 6), so there can be no doubt that Wallich was the collector of the material illustrated by Harvey.

BM000676840 (herb. Wilson) is annotated 'H.1204 *Syrrhopodon repens* Harvey H. Ic. Pl. t. 22 f. 4 (origl sp$^{n.}$) E. Indies Wallich.' and, in another hand, 'type'. We therefore take that to be original material. Long (1995: 22) noted that the original material in Harvey's herbarium in Trinity College, Dublin (TCD) is given as 'Nepal, Wallich 79', but he considered Penang to be the correct locality because all reports from Nepal were considered erroneous, based on mislabelled Wallich material. Long (1995: 22) noted the existence of another likely specimen of H.1204 in BM (herb. Hooker), but we have not seen it.

BM000676839 is annotated 'H.653. "Orthotrichum undulatum" H. Greville. Ternate J.D. 93 (Syrrhop. repens Harvey', with a further note 'Differs only from Harvey's sp^{n} in the leaves not being furnished with a pellucid border.' BM000676841 (herb. Wilson) is annotated 'H.653 "Orth. undulatum H. Grev. Mss" Ternate J.D. Leaves mod^{y} spreading crowded, denticulate with pellucid border, undulated. Capsule pale elliptical and calyptra (fide Hook.) pilose. *Syrrhopodon* ?sp.' Then in a different hand, '*S. repens* Harvey' (twice) and 'original spec^{n}'. BM 000676838 and BM000676842 (herb. Wilson) have similar annotations and the same herbarium number, H.653.

We interpret the annotations on the 'H.653' specimens to refer to a manuscript name 'Orthotrichum undulatum' used by Greville, based on J.D. Hooker 93 collected on the island of Ternate in Indonesia, and that this material was identified as *S. repens* subsequent to the publication of *S. repens*. The annotation 'original

spec^{n}' on BM000676841 we take to refer to the original specimen of 'Orthotrichum undulatum', not *S. repens*. Thus, we considered that the only original material of *S. repens* is the specimen BM000676840, and as the only original material this specimen is therefore the holotype (Art. 9.1(b)), as indicated above.

Because the protologue of *Syrrhopodon undulatus* Broth. & Geh. cites only material 'in herb. Melbourne', that material must be considered the original material. A likely holotype in MEL is filed under Bryidae, collected in 1895 on Bellenden Ker by Mrs Gribble, but a thorough search of MEL collections is needed in case multiple gatherings or specimens exist there.

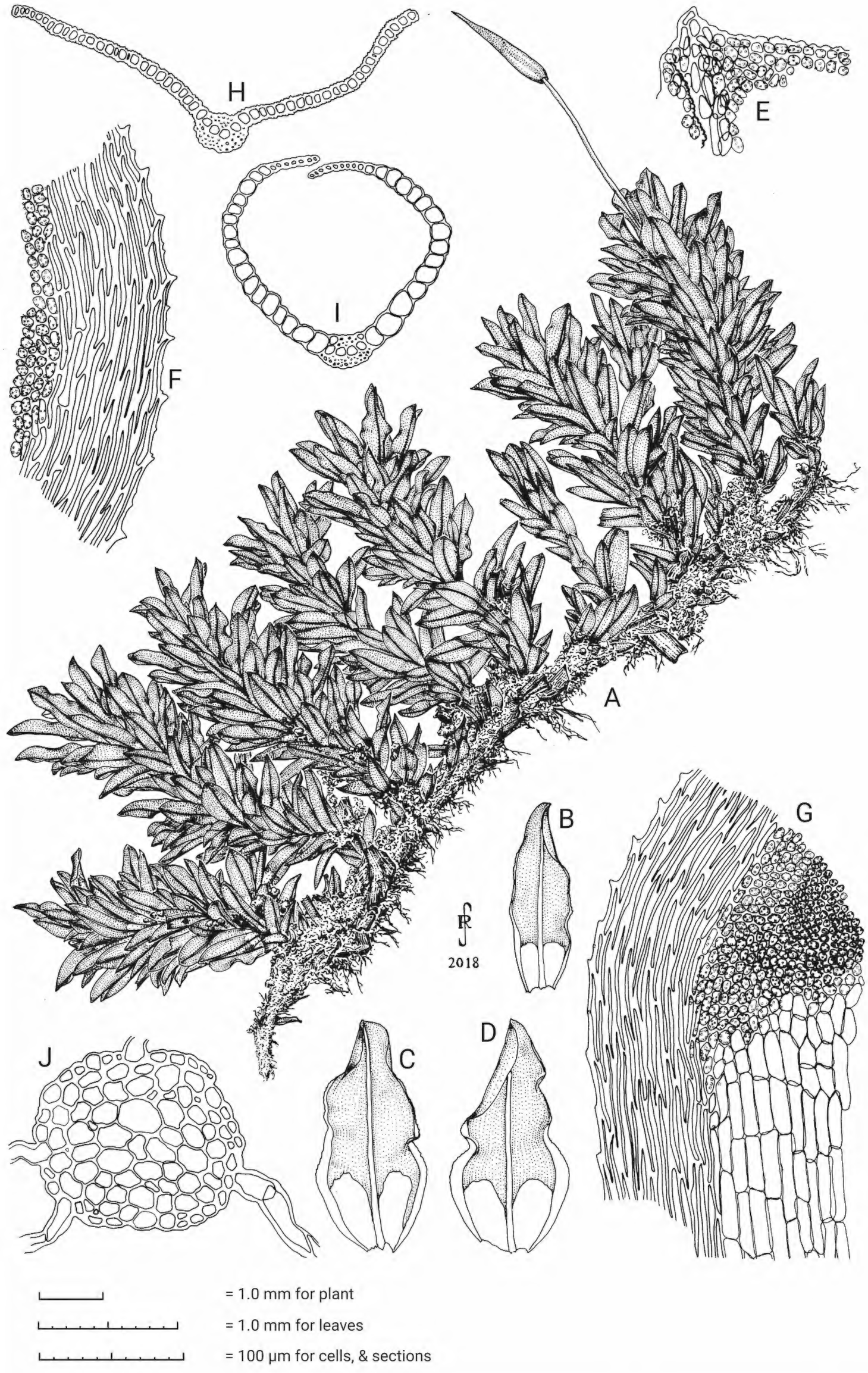

Fig. 8. *Mitthyridium repens* (Harv.) H.Rob. **A:** Habit of plant, drawn moist. **B–D:** Branch leaves. **E:** Cells of leaf apex. **F:** Cells from lower limb of leaf, just above shoulder region. **G:** Cells of leaf shoulder. **H:** Section of middle leaf lamina. **I:** Section through sheathing base of leaf. **J:** Stem section. Drawn from: *S.L.Thomson, B.Anau et al. SLT 17015*.

9. *Mitthyridium subluteum* (Müll.Hal.) Nowak, *Bryophyt. Biblioth.* 20: 144 (1980). *Codonoblepharum subluteum* Müll.Hal., *J. Mus. Godeffroy* 3(6): 67 (1874).

Original material: 'Patria. Upolu et Savaii.'

Type: Samoa: Upolu, 1864, *E.Graeffe s.n.* lectotype (designated by Nowak 1980: 144): H, not seen; isolectotypes: BM000662456!d, BM000662457!d, NY.

Illustration: Nowak (1980: 145).

Plants green to yellowish, forming loose soft tangles or thin spreading mats. Stems and branches elongate. Leaves (1–)2.0–3.5 mm long, narrowly linear to lanceolate-acuminate, sheathing base not or only slightly wider than limb, tips gradually acuminate, not expanded at apex, erect-spreading when moist, margins ±undulate; loosely curled-contorted when dry; margins dentate, typically undulate, strongly bordered almost to apex; cells of limb thick-walled, with small lumina, smooth to finely and minutely papillose; hyaline lamina short, reaching 1/5 or less of leaf length, narrowly to broadly scalariform distally to ± truncate. Gemmae inconspicuous, few in number, arising from both surfaces at leaf tips. Sporophytes not seen in Australian material. (Fig. 9)

Diagnostic characters: Eddy (1990) and Menzel and Schultze-Motel (1990) include *M. subulatum* as a synonym of *M. jungquilianum* (Mitt.) H.Rob., a species widely distributed in Malesia and the western Pacific Islands, together with *M. perundulatum*. Eddy (1990) also indicated that, apart from being much smaller and of more delicate stature, *M. jungquilianum* seemed similar to *M. luteum*, although the hyaline lamina is much shorter. After examining many specimens from Malesia and the western Pacific, Eddy (1990) postulated that there may be a clinal series of forms. Further study, particularly at the molecular level, is needed to clarify the relationships of these forms and species. Reese *et al.* (1986a) also suggested that *M. subluteum* may be a much smaller and more delicate form of *M. luteum*. They further indicated that *M. jungquilianum* had a grass-like appearance when dry 'due to the inrolling of the leaf lamina' and further that *M. flavum* differed in its broader leaves that are only 'folded when dry, not tubular and curved to resemble grass' and by its entire-margined leaves. The hyaline lamina of *M. subluteum* is very short relative to the total length of the leaf compared to that in *M. jungquilianum*. However, this is at odds with the illustration (Fig. 253, p. 137) of the leaves of the latter species in Eddy (1990), where they are also depicted as short relative to total leaf length.

In the absence of further study and definitive evidence to the contrary, it seems prudent to retain *M. subluteum* as the name applied to the Australian material. *Mitthyridium jungquilianum* (basionym *Syrrhopodon jungquilianus* Mitt 1856) has nomenclatural priority over *M. subluteum* (basionym *Syrrhopodon subluteus* Müll.Hal. 1874) should the two species be united.

Distribution: North-eastern Queensland from Cape Tribulation south to Cardwell (Fig. 10.9). Also known from Malesia, Philippines, Solomon Islands, western Samoa, Fiji, and reported from Gabon in western Africa.

Habitat: Grows on trees, shrubs, logs, rarely on rock, in moist rainforests, to 1300 m altitude.

Selected specimen seen: Queensland: Graham Range communication towers access road, Bramston Beach, 8 Nov 2014, *A.J.Franks AJF1411013* (BRI AQ0910211).

Etymology: Latin *sub* (almost) + *luteum* (yellow), referring to the great similarity to *Mitthyridium luteum* at first glance.

Typification: The collection date is taken from an annotation in BM-000662457.

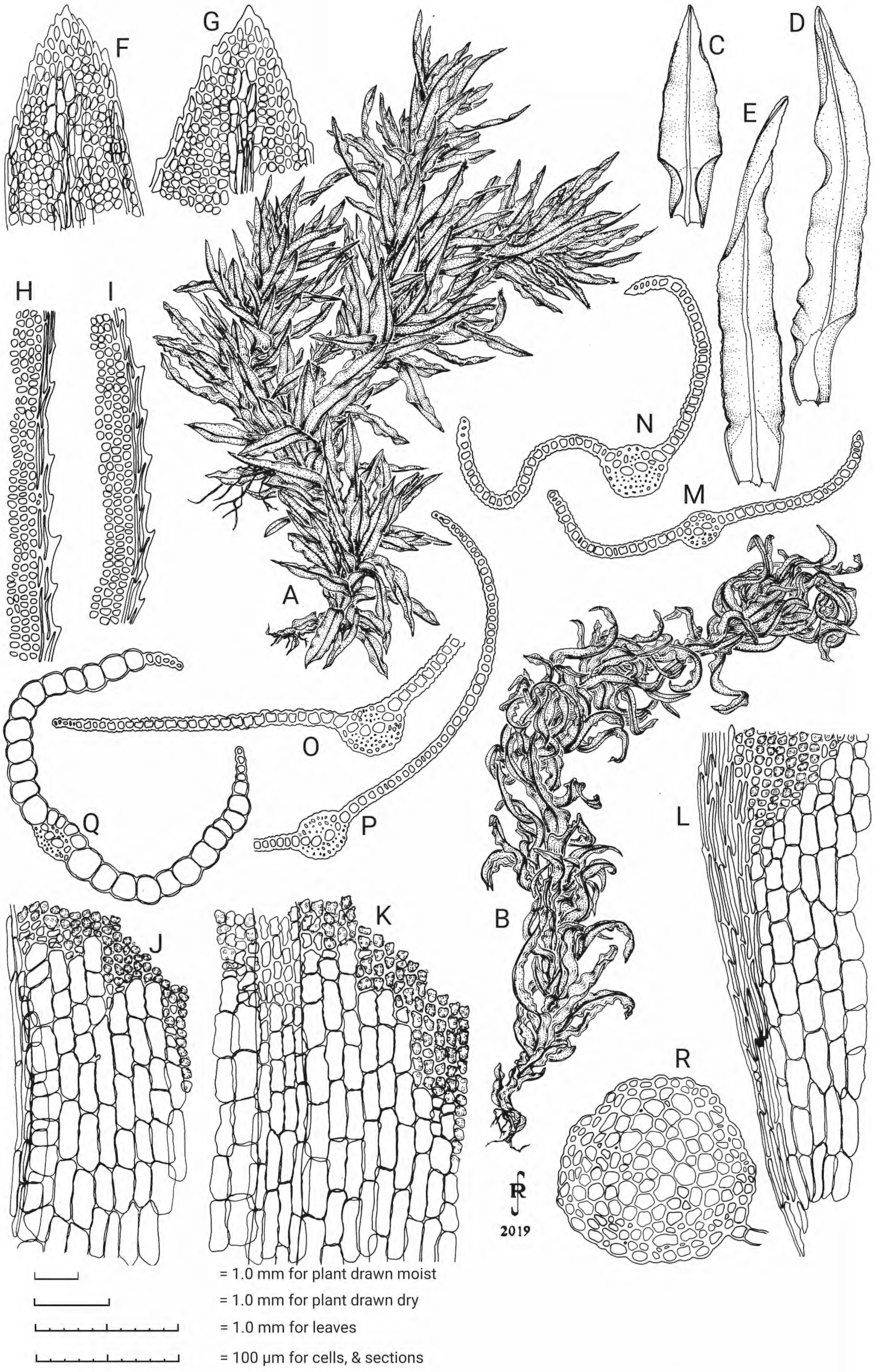

Fig. 9. *Mitthyridium subluteum* (Müll.Hal.) Nowak. **A:** Habit of plant drawn moist. **B:** Habit of plant drawn dry. **C–E:** Leaves. **F, G:** Cells of leaf apex (F – adaxial; G – abaxial). **H, I:** Mid lamina marginal cells, papillae omitted for clarity. **J, K:** Cells of hyaline lamina adjacent to costa. **L:** Cells of hyaline lamina and marginal border. **M–P:** Sections of leaf limb. **Q:** Section of sheathing leaf base. **R:** Stem section. Drawn from *A.J.Franks AJF1411013*.

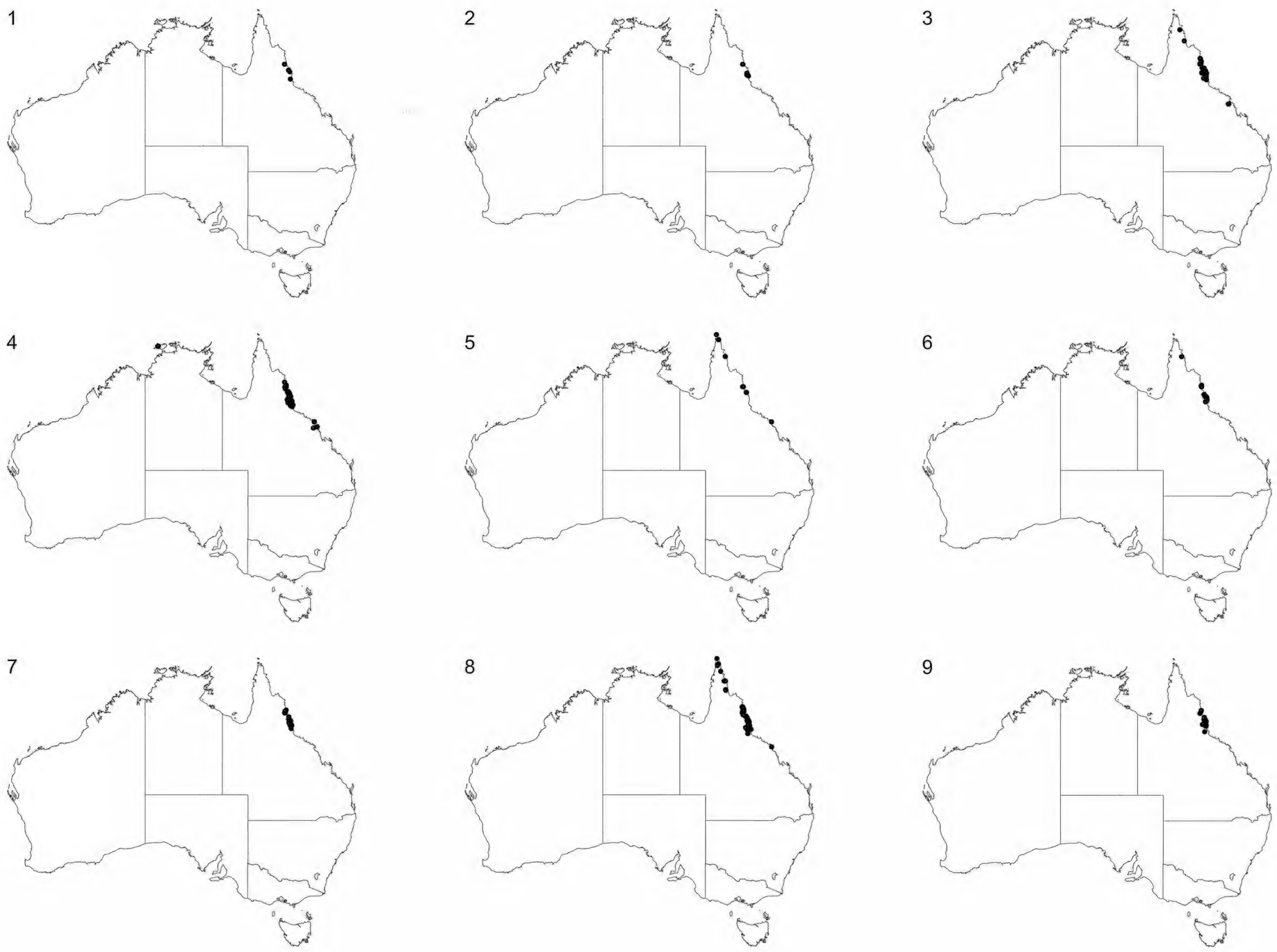

Fig. 10. Distribution of *Mitthyridium* species in Australia. **1** *Mitthyridium constrictum*, **2** *Mitthyridium crassum*, **3** *Mitthyridium fasciculatum*, **4** *Mitthyridium flavum*, **5** *Mitthyridium leucoloma*, **6** *Mitthyridium luteum*, **7** *Mitthyridium perundulatum*, **8** *Mitthyridium repens*, **9** *Mitthyridium subluteum*. (Source: Australasian Virtual Herbarium, accessed October 2020)

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Resolution of a 35-year taxonomic dilemma: *Eucalyptus* sp. Howes Swamp Creek (Myrtaceae) from eastern Wollemi National Park, New South Wales

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Abstract

The identity of a population of eucalypts from Howes Swamp Creek in the eastern part of Wollemi National Park in New South Wales has remained unresolved for over 35 years. Despite several workers inspecting both the site and the trees growing there over this period, little consensus has been achieved on its taxonomic status. Various suggestions have been made that the entity was a new species with affinities to *Eucalyptus dalrympleana, E. viminalis* or *E. bridgesiana*, and at one time the unpublished manuscript name *E. 'wollemiensis'* was used. Because of the perceived small population size and threats posed by wildfire and other factors, the entity phrase name *E.* sp. Howes Swamp Creek (M.Doherty 26) was listed as an endangered taxon in both Commonwealth and State threatened species legislation. Our investigations over the last few years, involving field, seedling, and herbarium studies, have determined the original reference specimen designated for the phrase name is *E. bridgesiana*, and that the population from which the specimen was gathered comprises a hybrid swarm of *E. bridgesiana* × *E. viminalis*. Both parent species are present at the site, although the former species is seemingly very rare there. We recommend that *E.* sp. Howes Swamp Creek be removed from threatened species legislation, and that the names *E.* sp. Howes Swamp Creek (M.Doherty 26) and *E. 'wollemiensis'* ms be considered nomenclatural synonyms of *E. bridgesiana*.

Introduction

During university studies undertaken by Michael Doherty within the Mellong Swamps region of eastern New South Wales in the mid-1980s, an anomalous, sterile eucalypt specimen (*M.Doherty 26*) was lodged at the National Herbarium of New South Wales (NSW). The identity of this specimen could not be determined by Doherty or others at that time, but it was recognised as belonging to *Eucalyptus* sect. *Maidenaria* based on the morphology of its juvenile leaves. Notes associated with this specimen stated that it was from a 'clump of juveniles, all with immature leaves'. A second collection from this site including buds and fruit was collected by Doherty in March 1988 (*M.Doherty 27*), with notes stating that it was from a 'population of juveniles and small adults (10 m) with sucker growth. Very few adult trees. Scattered "mallee-like" juveniles'. Eucalypt taxonomist

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Ken Hill subsequently visited and collected from the site on three separate occasions over an eight-year period in the 1990s, ultimately referring to the population by the unpublished manuscript name *E. 'wollemiensis'*. Duplicate specimens collected by Hill in November 2000 and lodged at CANB have been re-determined there by Andrew Slee as *E. bridgesiana*.

Later gatherings from the population in 2017 by one of us (GP) noted small trees to 8 m in height showing superficial similarities to *E. viminalis*, but with inflorescences in 7s, and nearby young plants with cordate juvenile leaves. This combination of features (*viz.* cordate juvenile leaves and 7-flowered inflorescences), combined with the mostly smooth texture of the bark, confounded its positive identification. Over a 15-year period, notes associated with several collections (e.g. *M.Doherty 26* in 1985; *M.Doherty 27* in 1988; *K.D.Hill 5648B* in 2000) include observations that the area appears to be regularly burnt. In addition, our own observations made in 2009 and in more recent years (2019 and 2020) suggest that fire is indeed a regular occurrence, and while this has allowed ready collection of juvenile coppice growth, at the same time it has hindered the collection of flowering and fruiting material.

PlantNet (2022) refers to this population as *E.* sp. Howes Swamp Creek (M. Doherty 26), with additional notes under the entry for *E. bridgesiana* that it is nearest to this species but is poorly understood, and under *E. viminalis* that specimens from Howes Swamp exhibiting bluish juvenile leaves may represent a separate taxon. Klaphake (2012) has referred to the Howes Swamp Creek population as *E. bridgesiana* × *E. viminalis* hybrids, while Slee *et al.* (2015) consider the plants to simply represent a population of *E. bridgesiana* with smaller than usual juvenile leaves and less prominently erect, exsert valves in the fruit. Bell (2008) and Hager and Benson (2010) both note the presence of the population under the unpublished name *E. 'wollemiensis'* but offer no further taxonomic opinion.

In 2000, *E.* sp. Howes Swamp Creek (M. Doherty 26) was listed federally as endangered in the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth of Australia 2000), having been previously listed as endangered in the NSW *Threatened Species Conservation Act 1995* (now replaced by the *Biodiversity Conservation Act 2016*) in 1995. Both listings were based on the few available herbarium records offering limited species knowledge, small population size and the threats posed to individuals by frequent fire (NSW Department of Planning and Environment 2019). In New South Wales, the taxon has been allocated to the 'data-deficient' stream of the Saving our Species conservation program, its uncertain taxonomy delaying the provision of management funding to ensure long-term survival.

Over the course of 35 years, specimens of *E.* sp. Howes Swamp Creek have been variously determined as *E. 'wollemiensis'* ms, *E.* sp. aff. *dalrympleana*, *E.* sp. aff. *viminalis*, *E. bridgesiana*, and *E. bridgesiana* × *E. viminalis* hybrids. It is clear that a resolution of its taxonomy is required, and hence this paper outlines the results of field and herbarium studies, including seedling trials, to determine the most appropriate taxonomic outcome.

Field investigations

Habitat

Several visits to Howes Swamp Creek have been undertaken by the authors over a period of 30 years, with most effort expended over the last ten. Survey of the northern side of Howes Swamp Creek undertaken in 1992 by one of us (SB) failed to confidently locate *E.* sp. Howes Swamp Creek, with only *E. viminalis* being observed. Attempts made in 2009 by SB and DN to relocate the taxon on two separate occasions were thwarted by wildfire that had impacted the area, leaving little material worthy of collection or inspection. From 2016, further visits to the site were undertaken by GP, and in 2017 fertile material and juvenile leaves of both the purported taxon and *E. viminalis* were located and examined.

More detailed inspection of the site in late 2019 by SB and GP incorporated a targeted search of the northern side of Howes Swamp Creek, recording 14 individuals of the putative taxon. During this time, juvenile leaves from epicormic growth from all individuals were collected, together with buds, fruit and adult leaves on trees large enough to support these. Two kilometres of Howes Swamp Creek were examined, with individuals located only within a 500 m stretch (Fig. 1).

All located individuals occurred within a narrow band between the swampy riparian zone of Howes Swamp Creek and the nearby sandstone escarpment running parallel to the length of the creek. The occupied zone comprised a canopy of *Angophora floribunda*, with occasional small individuals of *E. parramattensis* subsp. *parramattensis* and *E. amplifolia* subsp. *amplifolia*, over an understorey of *Acacia parramattensis, Persoonia linearis, Grevillea mucronulata, Melaleuca thymifolia, Gompholobium latifolium, Pteridium esculentum, Monotoca scoparia* and *Dianella revoluta* (Fig. 2). Howes Swamp Creek itself at this point is dominated by

emergent *E. amplifolia* subsp. *amplifolia*, over dense thickets of *Leptospermum juniperinum* and *Callistemon citrinus*. Upslope from the creek, dry open forest dominated by *E. piperita* occurs, with occasional individuals of *Corymbia eximia*. Upstream from the habitat supporting the purported taxon, *E. viminalis* is prominent, but this species is not present in the habitat occupied by *E.* sp. Howes Swamp Creek. Inspections further downstream of this area identified a dryer shrubby forest dominated by *E. racemosa*.

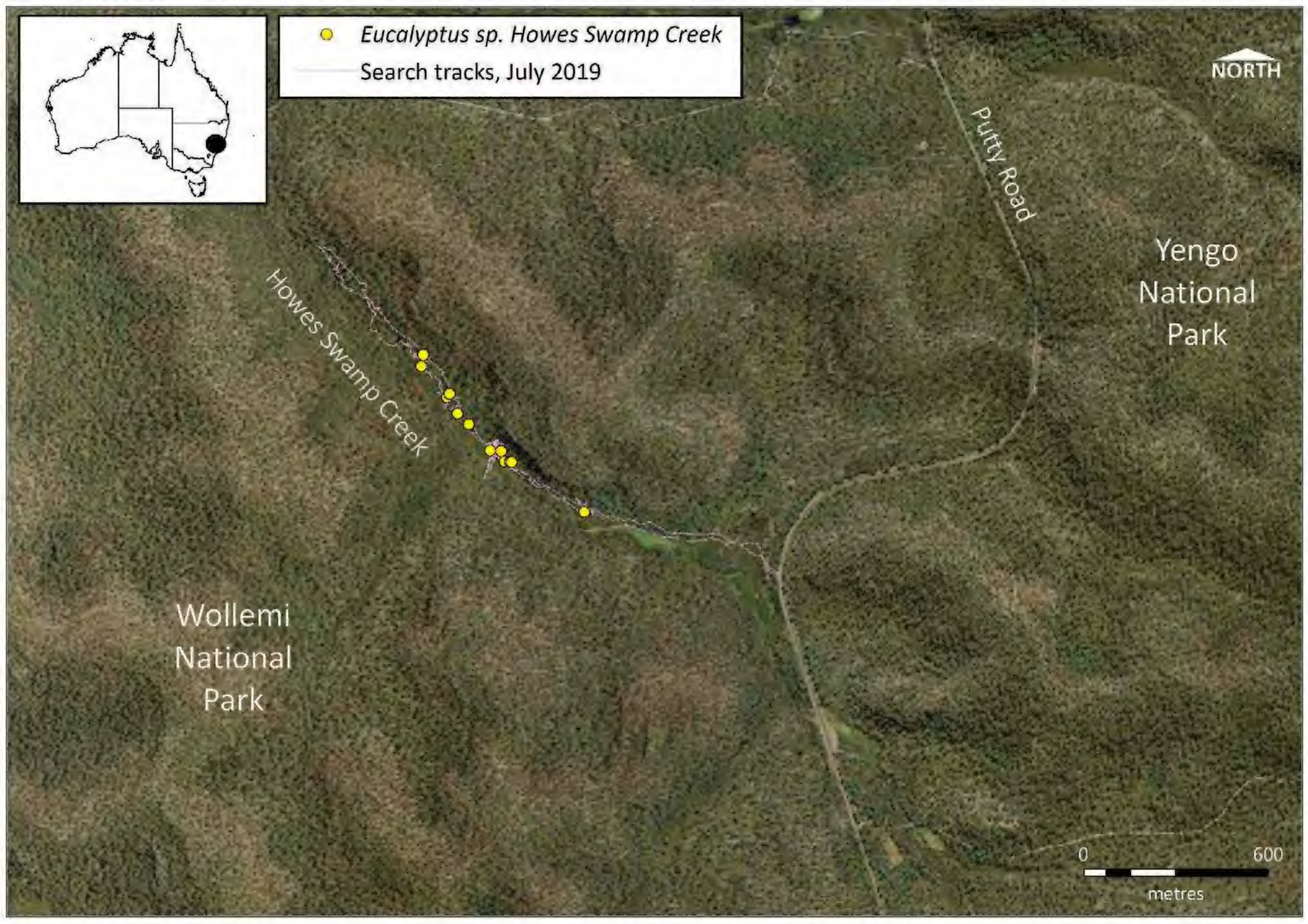

Fig. 1. Location of all individuals previously determined as *Eucalyptus* sp. Howes Swamp Creek.

Fig. 2. Habitat of *Eucalyptus* sp. Howes Swamp Creek, with one tree indicated by pink tape just right of centre. All other larger, rough-barked trees shown are *Angophora floribunda*.

Morphology

A wide range of juvenile leaf forms were evident in the 14 trees examined at the site in 2019. These ranged from the broadly cordate and alternate juvenile leaves typical of *E. bridgesiana*, to those with broad-lanceolate, opposite leaves more similar to *E. viminalis* (Fig. 3). Such variation within a relatively small area of habitat is suggestive of more than one taxon evident in the population. The colour of the juvenile foliage varied among individuals, with those nearer to the western edge of the population being glaucous and bluish like those of typical *E. bridgesiana*, while plants further east were greener like *E. viminalis*. The west-to-east shift was also evident in leaf shape, with the more cordate leaves (near to *E. bridgesiana*) grading to oblong-lanceolate and lanceolate forms closer to stands of pure *E. viminalis*.

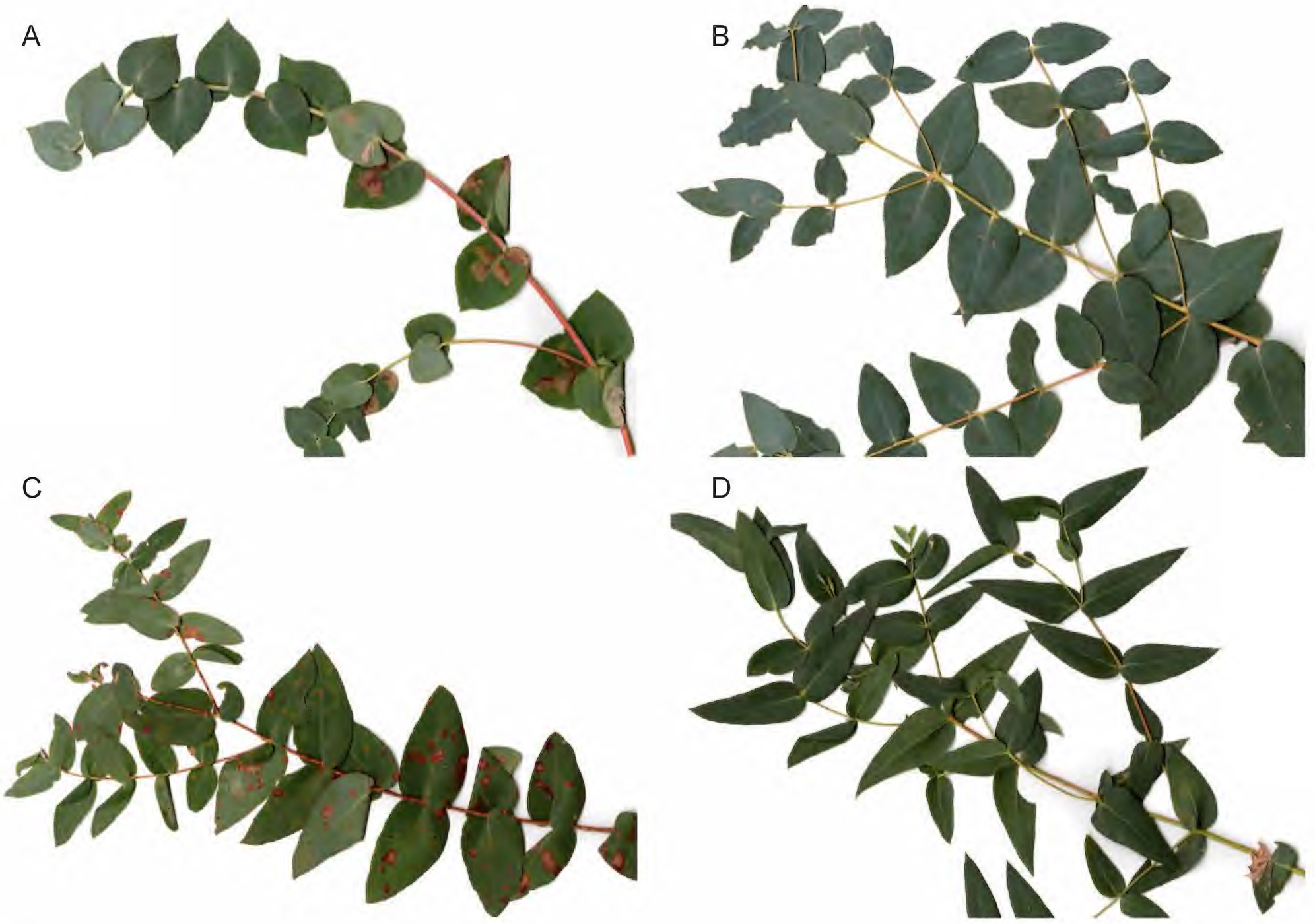

Fig. 3. Variation in juvenile leaf morphology exhibited within the population in 2019: a. Tree 1, *Eucalyptus bridgesiana*, showing characteristic cordate leaves with alternate arrangement; b. Tree 7, *E. bridgesiana* × *E. viminalis*, bluish tinge; c. Tree 11, *E. bridgesiana* × *E. viminalis*, green tinge with broad leaves; d. Tree 6, *E. bridgesiana* × *E. viminalis*, green tinge with narrower leaves.

Fertile material was only evident in one tree ('Tree 7') during our visit in 2019 (Fig. 4), and the buds obtained at that time were arranged in 7's (typical of *E. bridgesiana*). Fruit collected from that same tree in 2017 were within the range of variation expected for *E. bridgesiana* (Fig. 5), however juvenile leaves were intermediate between this species and *E. viminalis* (see Fig. 3b).

Two sapling-stage individuals observed in 2019, Trees 1 and 7, were of upright form and to c. 8 m high. Tree 7 exhibited rough, compacted bark on the basal third of the trunk, with the upper trunk and branches smooth. This form is typical of similarly aged *E. bridgesiana*, though the upper smooth bark shedding in short ribbons above basal rough bark is more reminiscent of *E. viminalis*. All the juveniles recorded in 2017 and 2019 were single- or multiple-trunked plants with a gnarled appearance, scarcely exceeding 2 m high and not bearing any fertile material. They all appeared to arise from lignotubers (Fig. 5), a trait known in both *E. bridgesiana* and *E. viminalis*, and no doubt this permitted these plants to survive the frequent fire regime of the area. Regular resprouting following fire may help to explain the apparent lack of mature *E. bridgesiana* in 2017 or 2019, with this isolated population continually reduced to coppice growth from aging lignotubers struggling to produce fertile material between fire events.

Fig. 4. Adult lanceolate foliage of *Eucalyptus bridgesiana* × *E. viminalis*, showing 7-flowered inflorescences (Tree 7).

Fig. 5. *Eucalyptus bridgesiana* × *E. viminalis*; fruit collected in 2017 (Tree 7, left), and bulbous lignotuber (Tree 1) in 2019 (right).

Herbarium investigations

Examination of herbarium specimens at NSW shows a confusing history of name use for *E.* sp. Howes Swamp Creek. However, most specimens could be accommodated in two groups: 1) typical *E. bridgesiana,* and 2) hybrids with *E. viminalis* (Table 1). The earliest specimens, collected by Doherty from '*800 m W of Putty Rd*', including the reference specimen *M.Doherty 26*, consist of only juvenile foliage, with the cordate, amplexicaul juveniles clearly blue-green, crenulate and soon alternating on the stem, typical of *E. bridgesiana.* The specimens are noted as coming from a '*clump of juveniles, all with immature leaves*', and from Doherty's second collection in 1988 (*M.Doherty 27*) as a '*Population of juveniles and small adults (10 m) with sucker growth. Very few adult trees. Scattered "mallee-like" juveniles*'. The 7-flowered, ovoid buds and hemispherical fruits with a raised annular disc on *M.Doherty 27*, collected 3 years later than *M.Doherty 26*, also align well with *E. bridgesiana*. Consequently, *E.* sp. Howes Swamp Creek (M. Doherty 26) is here considered a taxonomic synonym of *E. bridgesiana*.

Table 1. Herbarium specimens and proposed determinations.

Primary collector and number	Initial identification	Collection date	Location	Buds/ fruit?	Juvenile leaves?	Hill determination c. 2000	Our determination
M. Doherty 26	*E. dalrympleana* subsp. *dalrympleana* changed to *E.* sp. Howes Swamp Creek	19/07/1985	Howes Swamp Creek, 800 m west of Putty Road,	N	Y	*E. wollemiensis* ms.	*E. bridgesiana*
M. Doherty 27	*E. dalrympleana* subsp. *dalrympleana* changed to *E.* sp. Howes Swamp Creek	12/03/1988	Howes Swamp Creek, 800 m west of Putty Road,	Y	Y	*E. wollemiensis* ms.	*E. bridgesiana*
K.D. Hill 4169	*E. viminalis*	15/06/1992	Howes Swamp Creek, N side, 500 m W of Windsor Road	Y	N	*E.* aff. *viminalis*	*E. viminalis*
K.D. Hill 4170	*E. viminalis*	15/06/1992	Howes Swamp Creek, N side, 500 m W of Windsor Road	N	Y	*E.* aff. *viminalis*	*E. viminalis*
K.D. Hill 4167	*E. wollemiensis*	15/06/1992	Howes Swamp Creek, N side, 800 m W of Windsor Road	Y	N	*E. wollemiensis* ms.	*E. bridgesiana*
K.D. Hill 4168	*E. wollemiensis*	15/06/1992	Howes Swamp Creek, N side, 800 m W of Windsor Road	N	Y	*E. wollemiensis* ms.	*E. bridgesiana*
K.D. Hill 5018	*E. wollemiensis*	15/01/1999	Howes Swamp Creek, N side, 500 m W of Windsor Road	Y	Y	*E.* aff. *viminalis*	*E. bridgesiana* × *viminalis*
K.D. Hill 5019	*E. wollemiensis*	15/01/1999	Howes Swamp Creek, N side, 500 m W of Windsor Road	Y	N	*E.* aff. *viminalis*	*E. bridgesiana* × *viminalis*
K.D. Hill 5073	*E. wollemiensis*	5/11/1999	Howes Swamp.	N	Y	*E.* aff. *viminalis*	*E. bridgesiana* × *viminalis*
K.D. Hill 5648A	*E. wollemiensis*	30/11/2000	Howes Swamp.	Y	N	*E. wollemiensis* ms.	*E. bridgesiana*
K.D. Hill 5648B	*E. wollemiensis*	30/11/2000	Howes Swamp.	Y	N	*E. wollemiensis* ms.	*E. bridgesiana*
K.D. Hill 5648C	*E. wollemiensis*	30/11/2000	Howes Swamp.	N	Y	*E. wollemiensis* ms.	*E. bridgesiana*
K.D. Hill 5650	*E. wollemiensis*	30/11/2000	Howes Swamp.	N	Y	*E. wollemiensis* ms.	*E. bridgesiana*
K.D. Hill 5649	*E. wollemiensis*	30/11/2000	Howes Swamp.	N	Y	*E. wollemiensis* ms.	*E. bridgesiana*
R.L. Johnstone 2758	*E.* sp. aff. *viminalis*	19/05/2010	c. 500 metres west of the Putty Road on Howes Swamp Creek (north side of swamp)	Y	N	-	*E. bridgesiana* × *viminalis*
G.P. Phillips 133	*E.* sp. aff. *viminalis*	21/09/2016	Howes Swamp Creek, on river flat on N side of creek c. 650 m from Putty Rd	Y	N	-	*E. bridgesiana* × *viminalis*
G.P. Phillips 132	*E.* sp. Howes Swamp Creek	21/09/2016	Howes Swamp Creek, on North side of creek c. 700 m from Putty Rd	Y	N	-	*E. bridgesiana* × *viminalis*
G.P. Phillips 343	*E.* sp. Howes Swamp Creek	27/07/2017	N edge of Howes Swamp Creek, c. 1 km W of Putty Rd	N	Y	-	*E. bridgesiana*
G.P. Phillips 342	*E.* sp. Howes Swamp Creek	27/07/2017	N edge of Howes Swamp Creek, c. 1 km W of Putty Rd	Y	N	-	*E. bridgesiana* × *viminalis*

Table 2. Herbarium specimens of cultivated seedlings. Specimens held at NSW and grown from wild source seed collected from plants attributed to *E.* sp. Howes Swamp Creek.

Seed Source Collection	Seedling Specimen Reference No.	Harvest Date	Collector	Leaf Shape	Leaf Colour	Leaf Margin	Leaf Arrangement	Our Determination
K.D. Hill 5018	NSW 438624	9/03/2000	*Anon. s.n.*	Lanceolate to 30 mm wide	Blue-green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 438626	9/03/2000	*Anon. s.n.*	Lanceolate	Green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 518106	5/05/2000	*Anon. s.n.*	Lanceolate	Blue-green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 446535	1/11/2000	*Anon. s.n.*	Narrow-lanceolate	Green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 446536	1/11/2000	*Anon. s.n.*	Lanceolate	Green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 1115673	2/04/2021	G.P. Phillips *s.n.*	Lanceolate with 1 branch of ovate	Grey-green	Entire	alternate	*E. bridgesiana* × *viminalis*
	NSW 1115674	2/04/2021	G.P. Phillips *s.n.*	Lanceolate to 25 mm wide	Grey-green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 1115675	2/04/2021	G.P. Phillips *s.n.*	Narrow-lanceolate	Grey-green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 1115676	2/04/2021	G.P. Phillips *s.n.*	Narrow-lanceolate	Grey-green	Entire	opposite	*E. bridgesiana* × *viminalis*
	NSW 1115677	2/04/2021	G.P. Phillips *s.n.*	Lanceolate	Grey-green	Entire	opposite	*E. bridgesiana* × *viminalis*
K.D. Hill 5648A	NSW 518122	17/07/2001	*Anon. s.n.*	Ovate	Blue-grey	Crenulate	alternate	*E. bridgesiana*
	NSW 518123	1/03/2002	*Anon. s.n.*	Ovate	Blue-grey	Crenulate	alternate	*E. bridgesiana*

Ken Hill identified his 1992 collections as potentially comprising two taxa, including specimens sourced from the same area '*800 m W of Windsor Rd*' as collected by Doherty. Hill identified his material by proposing the manuscript name *E.* '*wollemiensis*' for the specimens morphologically similar to Doherty's (*K.D.Hill* 4167 and *K.D.Hill 4168*) and *E.* sp. aff. *viminalis* for other material from the site (*K.D.Hill 4169* and *K.D.Hill 4170*). Both taxa are represented as a pair of specimens from a mature plant as well as a nearby juvenile. The specimens matching Doherty's collections again display juvenile foliage, buds and immature fruit typical of *E. bridgesiana*. Hill's *E.* sp. aff. *viminalis* specimens though, despite his initial thoughts, appear typical of *E. viminalis*, bearing obovoid fruit with an obliquely raised disc, inflorescences in umbels of 3, and green, sessile, narrow-lanceolate juvenile leaves opposite for many nodes. These specimens are also only noted as being '*500 m W of Windsor Rd*' which approximates our observations of the known *E. viminalis* stand.

Hill's specimens from 1999 (*K.D.Hill 5018*, *K.D.Hill 5019*, *K.D.Hill 5073*) were also initially labelled by Hill as *E.* '*wollemiensis*' ms before later being re-determined by him to *E.* sp. aff. *viminalis*. These all show much broader lanceolate juvenile leaves than typically found in *E. viminalis* despite the more typical buds and fruit of that species. Seed propagated by Hill and lodged as juvenile plants at NSW (Table 2) show characteristics consistent with *E. bridgesiana* × *E. viminalis* (grown from *K.D.Hill 5018*) or *E. bridgesiana* (grown from *K.D.Hill 5648A*).

Growth trials

Seedlings grown by us, also sourced from *K.D.Hill 5018*, found all progeny were attributable to *E. bridgesiana* × *E. viminalis* (Table 3, Fig. 6). At 12 months of age, these seedlings had deteriorated in health considerably with 5 of 16 dying and 9 of the remaining 11 mildly to heavily scale infested and not progressing into mature growth phases. Several individuals produced shoots from their lignotubers, producing a number of weak basal stems which in most cases rapidly died off. Three randomly selected plants were maintained for a further 12 months but showed no further development or maturation despite regular removal of scale and daily watering. Reduced vigour and continual death of shoots and resprouting from their bases are suggestive of a weak hybrid origin.

Fig. 6. Seedling variation from the single maternal genotype (*K.D.Hill 5018*) showing evidence of hybridisation. Plant 4 (a) shows leaves broader than expected for *E. viminalis* and broader than all other seedlings in the batch, while Plant 9 (b) shows branches producing ovate, disjunct foliage.

Table 3. Seedling trial measurements. Source material was held at the Australian PlantBank in cold storage at -20°C. A sample of 20 seeds was sown on water agar in petri dishes in February 2020 and germinated in a climate-controlled cabinet at 20°C with 12 hours of light daily. Seedlings were potted into standard potting mixture after germination at 22 to 30 days and transferred to a heated glasshouse before finally moving into a polyhouse after 3 months. Seedlings were scored at 6 months of age. All plants had green, concolorous leaves that were sessile on the lower nodes and with rounded bases on the upper stem. Plants marked * had scattered oil glands (the others were not measured).

No	Stem		Leaves	Lower Stem (lowest 6 nodes)				Upper Stem (above node 6)		
	Height (mm)	Nodes expanded	Position	Lamina shape	Basal shape	Mean lamina width (mm)	Mean lamina length (mm)	Lamina shape	Mean lamina width (mm)	Mean lamina length (mm)
1	356	13	Opposite	narrow-lanceolate	amplexicaul	11	55	narrow-lanceolate	7	40
2*	447	15	Opposite	lanceolate	amplexicaul	12	53	narrow-lanceolate	10	49
3	395	12	Opposite	lanceolate	amplexicaul	12	57	narrow-lanceolate	10	72
4*	465	12	Opposite & disjunct	broad-lanceolate	amplexicaul	26	48	lanceolate	15	47
5*	400	13	Opposite	broad-lanceolate	rounded	16	60	lanceolate	13	52
6*	315	11	Opposite	lanceolate	rounded	19	57	lanceolate	18	43
7	395	11	Opposite	narrow-lanceolate	amplexicaul	17	46	lanceolate	10	41
8*	417	13	Opposite	lanceolate	rounded	14	55	narrow-lanceolate	11	63
9*	375	13	Opposite	lanceolate	rounded	16	50	lanceolate	10	33
10	417	12	Opposite	lanceolate	rounded	19	68	lanceolate	12	56
11	365	14	Opposite	lanceolate	rounded	19	50	narrow-lanceolate	11	62
12	392	13	Opposite	lanceolate	amplexicaul	-	-	narrow-lanceolate	12	52
13	330	11	Opposite	lanceolate	amplexicaul	15	52	lanceolate	12	41
14	345	11	Opposite	broad-lanceolate	amplexicaul	19	57	lanceolate	10	27
15*	397	12	Opposite	lanceolate	rounded	15	47	lanceolate	13	45
16	432	14	Opposite	narrow-lanceolate	amplexicaul	-	-	narrow-lanceolate	8	39
Mean	**390**	**13**				**16.4**	**53.9**		**11.4**	47.6

Visible oil gland frequency was also examined to provide additional supporting evidence of the hybrid nature in *E.* sp. Howes Swamp Creek. *Eucalyptus bridgesiana* (mean frequency 320 cm^{-2}, scattered) and *E. viminalis* (mean frequency 900 cm^{-2}, very numerous) differ considerably in oil gland density (Brooker and Nicolle 2013), and counts were undertaken of this trait on freshly grown seedlings. Despite most seedlings superficially resembling *E. viminalis*, a random selection of well-developed juvenile leaves from seven plants had a visible oil gland frequency in the range of 300 to 350 cm^{-2} (Fig. 7), as would be expected from the 'scattered' oil gland frequency of *E. bridgesiana.*

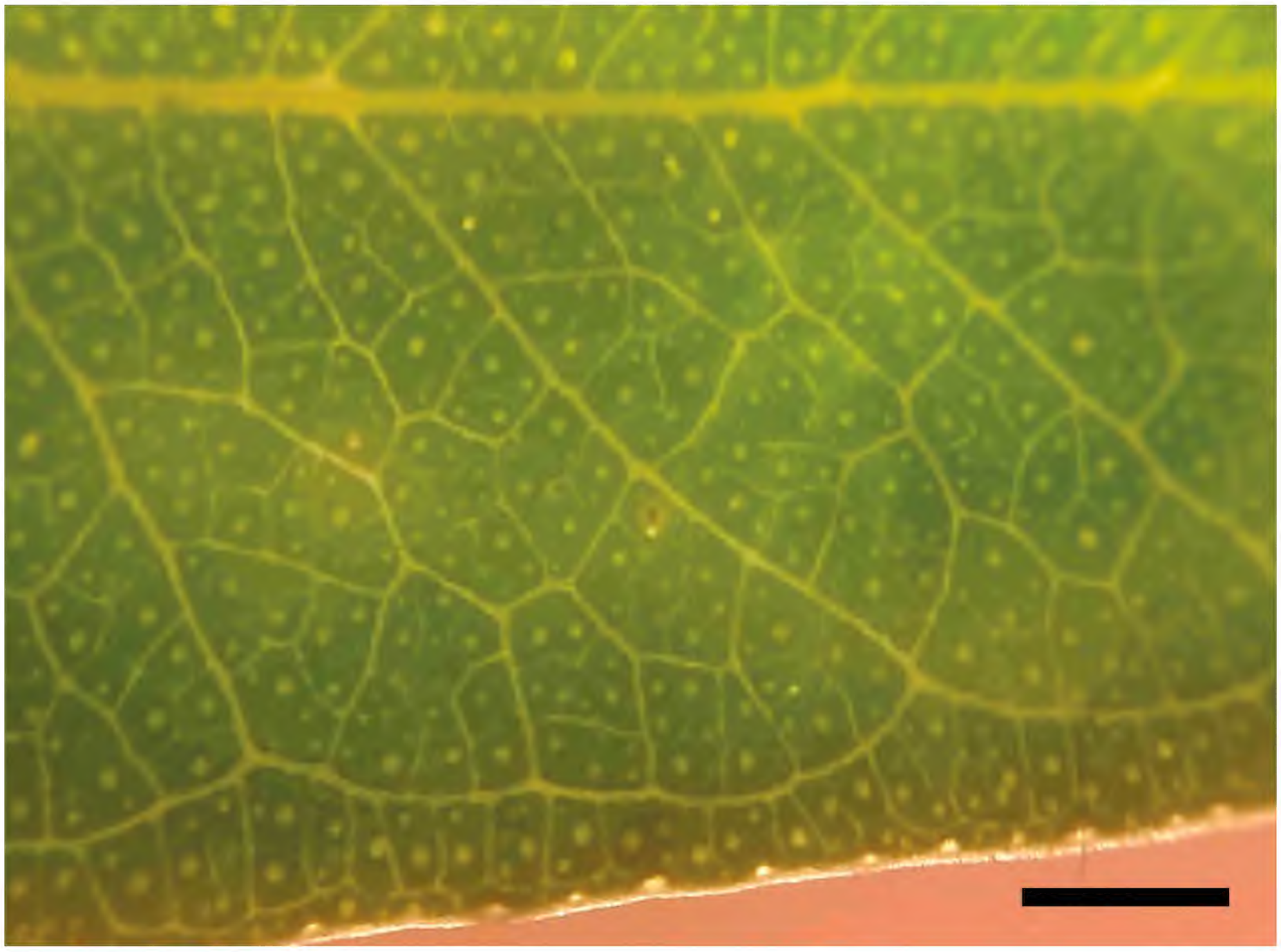

Fig. 7. Visible oil gland frequency of a representative leaf (Plant 7) in seedlings grown from seed (from *K.D.Hill 5018*). This leaf shows a frequency of approximately 300 per cm^2 consistent with that seen in adult leaves of *E. bridgesiana,* despite superficial morphological resemblance to the most narrow-leaved juveniles of *E. viminalis.* Scale = 2 mm.

Discussion

Our investigations are now able to shed light on the convoluted taxonomic history of *E.* sp. Howes Swamp Creek (M.Doherty 26). Despite several names and taxonomic hypotheses being proposed over the years, the concept of *E.* sp. Howes Swamp Creek conflates two entities: 1) a small, disjunct and remnant stand of *E. bridgesiana*, which is now rare in the area and reduced to a few, stunted individuals after a history of repeated fire; and 2) a hybrid swarm of *E. bridgesiana* × *E. viminalis,* comprising a number of plants of various forms and trait combinations, with evidence of back-crossing with the more prevalent *E. viminalis* which occurs upstream.

On review, the reference specimen for the phrase name *E.* sp. Howes Swamp Creek (M.Doherty 26), and several of the specimens included by Hill in the unpublished *E. 'wollemiensis'* ms, are within the expected range of variation exhibited by *E. bridgesiana*. The combination of cordate to ovate, amplexicaul, blue-grey juvenile leaves with crenulate margins soon becoming disjunct on the stem is unique to this taxon among eucalypts in New South Wales and allows for positive identification from juvenile specimens alone. Other populations of *E. bridgesiana* have been linked to novel species previously, but when placed into context across the entire distribution of this species, their differences are questionable. For example, *E. saxicola* J.T.Hunter, a species described in 2001 based on material from exposed outcrops on Mount Canobolas in the central

west of NSW, was differentiated from *E. bridgesiana* by its smaller stature, smaller juvenile leaves and slight differences in buds and fruit (Hunter 2001). However, *E. bridgesiana* exhibits wide variation in these features across its range and therefore populations exhibiting such subtle differences are insufficiently differentiated, potentially explainable by prevailing environmental conditions at specific sites (NSW Threatened Species Scientific Committee 2012; Slee *et al.* 2015). Both Slee *et al.* (2015) and Klaphake (2012) note that specimens from Howes Swamp Creek exhibiting similarly slight differences from typical *E. bridgesiana* do not fall outside of the expected variation of that species. The phrase name *E.* sp. Howes Swamp Creek (M.Doherty 26) should therefore be synonymised under that species. *Eucalyptus 'wollemiensis'* ms should be synonymised under *E. bridgesiana* in part and under *E. bridgesiana* × *viminalis* in part, given some specimens placed under that name by Hill are hybrids.

Examination of herbarium specimens collected over time and plants *in situ* suggest that the small population of *E. bridgesiana* at Howes Swamp Creek has persisted on the site despite its frequent fire history, though the evolutionary origin of this outlying population remains unknown. The nearest confirmed wild populations of *E. bridgesiana* occur some 34 km to the northwest in the Central Tablelands, so either a historical westerly range contraction to the drier, cooler higher altitudes of the tablelands has caused the isolation of this stand, or a chance dispersal to a novel habitat eastward has occurred. It is also possible that other small stands of *E. bridgesiana* remain undetected in the area given the large region of wilderness between these sites.

Hybrids are a relatively common feature in the eucalypts (e.g. Parsons and Kirkpatrick 1972; Potts and Reid 1983; Bennett 1995; Barbour *et al.* 2003; Hopper and McQuoid 2009), including parentage by *E. viminalis* which is known to hybridise with a number of other species including *E. aggregata* H.Deane & Maiden (Field 2008) and *E. camaldulensis* Dehnh. (Barson 1973). Some authors have argued for formal recognition of hybrids, particularly those where one or both parents have been removed through anthropogenic causes (e.g. Parsons and Zubrinich 2010), while others have investigated hybrid origins and questioned their conservation value. For example, Walker *et al.* (2009) analysed microsatellite variation in the West Australian *E.* × *bennettiae* D.J.Carr & S.G.M.Carr and suggested that the entity did not warrant conservation protection (although it currently still carries a P4 conservation code in that state). They examined key criteria in the context of Western Australian conservation policy to show that *E.* × *bennettiae* did not 'breed true' during germination experiments, was clonal and did not produce viable seed that maintained morphological features at the seedling stage (seedlings instead displaying segregation of parental characteristics), and hybrids were produced from a natural hybridisation process (not the result of anthropogenic disturbances). A similar conclusion can be applied to the *E. bridgesiana* × *E. viminalis* hybrid swarm at Howes Swamp Creek (but not *E.* sp. Howes Swamp Creek, synonymised here under *E. bridgesiana*), whereby seedling studies have shown wide variation in morphology, F1 plants observed in the field also show considerable variation, and a review of morphological traits evident in herbarium specimens collected over 35 years is explainable by the presence of this hybrid swarm.

The dominance of *E. viminalis* in Howes Swamp Creek, together with the restricted presence of *E. bridgesiana* in some locations, has in our opinion resulted in a population of hybrid forms showing varied morphology. This is particularly evident in the juvenile leaves of these hybrids, which on balance are more like *E. viminalis* than *E. bridgesiana*. We hypothesise that repeated back-crossing between these two postulated parent species has resulted in wide variation, and over time it is probable that the population will revert to more typical *E. viminalis*. From a conservation point of view, this means that little value is found in maintaining a conservation status for the hybrid entity as not only is it difficult to identify with its highly variable morphology, but the evidence of a post-zygotic barrier to reproduction resulting in reduced hybrid vigour and the continued back-crossing with *E. viminalis* means that decline in the population is a likely natural process. It is fortunate that the entire population lies within Wollemi National Park, as the only real threats to the remnant *E. bridgesiana* are likely to be repeated hot fires in quick succession and extended droughts as predicted through a changing climate. Despite this, most plants support well-developed lignotubers suggesting a history of resprouting following fire. Given the outcomes of our study, we propose that the endangered status of *E.* sp. Howes Swamp Creek (M.Doherty 26) be revoked, synonymising the reference specimen under *E. bridgesiana*, and recognising the wide morphological variation within the population at Howes Swamp Creek as a hybrid swarm between *E. bridgesiana* and *E. viminalis*.

Taxonomy

Eucalyptus bridgesiana R.T.Baker, *Proc. Linn. Soc. New South Wales* 23: 164 (1898). *Type*: New South Wales: Albury, 21 June 1897, *A.Andrews s.n.*; lecto: NSW 314589, designated by A.R.Bean, *Telopea* 12(3): 310 (2009).

Eucalyptus stuartiana var. *amblycorys* Blakely, *Key Eucalypts* 145 (1934); *E. bridgesiana* var. *amblycorys* (Blakely) Cameron, *Victorian Naturalist* 63: 41 (1946). *Type:* New South Wales: Tumut, January 1897, *E.Betche s.n.*; holo: NSW 315102; iso: HO 538775, *n.v.*

Eucalyptus saxicola J.T.Hunter, *Telopea* 9(2): 403 (2001). *Type*: New South Wales: Central Tablelands: Mt Canobolas State Recreation Area, c. 14 km south-west of Orange, 33° 20' 11" S, 154° 58' 22" E, on margin of trachyte outcrop, 1200 m altitude, *J.T.Hunter 8556*, 2 June 1998; holo: NSW; iso: BRI, CANB, MEL, all *n.v.*, apparently not distributed.

Eucalyptus '*wollemiensis*' ms, K.D. Hill; noted in Bell (2008) and Hager and Benson (2010), in part.

Eucalyptus sp. Howes Swamp Creek (M.Doherty 26), National Herbarium of New South Wales, PlantNET Flora of New South Wales Online https://plantnet.rbgsyd.nsw.gov.au/ (Accessed 17 May 2022).

Specimens examined: New South Wales: Central Coast: Howes Swamp Creek, 800 m west of Putty Road, Wollemi National Park, *M.Doherty 26*, 19 Jul 1985 (NSW 207054); Howes Swamp Creek, 800 m west of Putty Road, Wollemi National Park, *M.Doherty 27*, 12 Mar 1988 (NSW 207056); Howes Swamp Creek, N side, 500 m W of Windsor Road, *K.D.Hill 4167, L.A.S.Johnson & L.C.Stanberg,* 15 Jun 1992 (BRI *n.v.,* MEL 0231159A, NSW 256749); Howes Swamp Creek, N side, 500 m W of Windsor Road, *K.D.Hill 4168, L.A.S.Johnson & L.C.Stanberg,* 15 Jun 1992 (BRI *n.v.,* MEL 0231157A, NSW 256750); Howes Swamp, *K.D.Hill 5648A & L.C.Stanberg*, 30 Nov 2000 (NSW 449316); Howes Swamp, *K.D.Hill 5648B & L.C.Stanberg,* 30 Nov 2000 (AD *n.v.,* BRI *n.v.,* CANB *n.v.,* HO 529271, K *n.v.,* MEL *n.v.,* MO *n.v.,* NSW 449345); Howes Swamp, *K.D.Hill 5648C & L.C.Stanberg,* 30 Nov 2000 (CANB 584211.1, MEL *n.v.,* NSW 449348); Howes Swamp, *K.D.Hill 5649& L.C.Stanberg,* 30 Nov 2000 (CANB *n.v.,* MEL *n.v.,* NSW 449319); Howes Swamp, *K.D.Hill 5650& L.C.Stanberg*, 30 Nov 2000 (CANB *n.v.,* MEL *n.v.,* NSW 449318); Seedling grown from *K.D.Hill 5648 A* (Howes Swamp), *Anon. s.n.*, 17 Jul 2001 (NSW 518122); Seedling grown from *K.D.Hill 5648*A (Howes Swamp), *Anon. s.n.*, 1 Mar 2001 (NSW 518123); N edge of Howes Swamp Creek, c. 1 km W of Putty Rd, *G.P.Phillips 343*, 27 Jul 2017 (NSW 999615).

Eucalyptus bridgesiana* × *E. viminalis

Eucalyptus '*wollemiensis*' ms, K.D. Hill; noted in Bell (2008) and Hager and Benson (2010), in part.

Eucalyptus sp. Howes Swamp Creek, National Herbarium of New South Wales, PlantNET Flora of New South Wales Online https://plantnet.rbgsyd.nsw.gov.au/ (Accessed 17 May 2022), in part (as to the concept), but not including the reference specimen *M.Doherty 26*, which is *E. bridgesiana*.

Specimens examined: New South Wales: Central Coast: Howes Swamp Creek, N side, 500 m W of Windsor Road, *K.D.Hill 5018 & M.Turton,* 15 Jan 1999 (NSW 425911); Howes Swamp Creek, N side, 500 m W of Windsor Road, *K.D.Hill 5019 & M.Turton,* 15 Jan 1999 (AD *n.v.,* BRI *n.v.,* CANB 522143.1, DNA D0276752, HO 506652, K *n.v.,* MEL 2068393A, MO *n.v.,* NSW 425913, NY *n.v.,* PERTH *n.v.*); Howes Swamp, *K.D.Hill 5073& L.C.Stanberg*, 15 Jan 1999 (BRI *n.v.,* CANB *n.v.,* NSW 437925); seedling grown from *K.D.Hill 5018* (Howes Swamp Creek, N side, 500 m W of Windsor Road), *Anon. s.n.*, 9 Mar 2000 (NSW438624); seedling grown from *K.D.Hill 5018* (Howes Swamp Creek, N side, 500 m W of Windsor Road), *Anon. s.n.*, 9 Mar 2000 (NSW438626); seedling grown from *K.D.Hill 5018* (Howes Swamp Creek, N side, 500 m W of Windsor Road), *Anon. s.n.*, 5 May 2000 (NSW 518106); seedling grown from *K.D.Hill 5018* (Howes Swamp Creek, N side, 500 m W of Windsor Road), *Anon. s.n.*, Nov 2000 (NSW446535); seedling grown from *K.D.Hill 5018* (Howes Swamp Creek, N side, 500 m W of Windsor Road), *Anon. s.n.*, Nov 2000 (NSW446536); c. 500 metres west of the Putty Road on Howes Swamp Creek (north side of swamp), *R.L.Johnstone 2758, G.Errington, A.E.Orme, R.G.Coveny & J.P.Silk*, 19 May 2010 (NSW 862275); Howes Swamp Creek, on North side of creek c. 700 m from Putty Rd, *G.P.Phillips 132 & K.E.Willis*, 21 Sep 2016 (NSW 988725); Howes Swamp Creek, on river flat on N side of creek c. 650 m from Putty Rd, *G.P.Phillips 133 & K.E.Willis*, 21 Sep 2016 (NSW 988728); N edge of Howes Swamp Creek, c. 1 km W of Putty Rd, *G.P.Phillips 342*, 27 Jul 2017 (CANB *n.v.,* MEL *n.v.,* NSW 999614); seedlings grown from *K.D.Hill 5018* (Howes Swamp Creek, N side, 500 m W of Windsor Road), *G.P.Phillips s.n.*, 2 Apr 2021 (NSW 1115673, NSW 1115674, NSW 1115675, NSW 1115676, NSW 1115677).

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Pultenaea williamsii (Fabaceae: Mirbelieae), a new species endemic to the New England Tableland Bioregion of New South Wales

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Abstract

Pultenaea williamsii I.Telford, Clugston & R.L.Barrett (Fabaceae, Faboideae, Mirbelieae), endemic to the New England Bioregion, New South Wales, Australia, is described as new, segregated from the *P. flexilis–P. juniperina–P. blakelyi* species assemblage. Its distribution is mapped and habitat and conservation status are discussed.

Introduction

Pultenaea Sm. as currently circumscribed is a relatively large genus of over 150 species (Barrett *et al.* 2021; Renner *et al.* 2022) with most species found in south-eastern Australia. Orthia *et al.* (2005) suggested that generic circumscriptions in tribe Mirbelieae may need major revision. Barrett *et al.* (2021) analysed available data for the plastid *trn*L-F region and concluded that additional data would likely resolve relationships among members of the genus sufficiently to allow the core of *Pultenaea* to be maintained, and this new species belongs to the core of *Pultenaea*.

John Williams, a former lecturer in Botany, University of New England, collected in 1961 what he considered to be a new species of *Pultenaea* Sm. near Yarrowyck, which is located on the western fall of the New England Tableland, west of Armidale, New South Wales. The specimen has been subsequently identified variously as *P. juniperina* var. *planifolia* H.B.Will. and *P. juniperina* var. *mucronata* (Benth.) Corrick. Application of these names is much confused as demonstrated by the following usage. Thompson (1961) accepted *P. juniperina* var. *planifolia*, including *P. flexilis* var. *mucronata* Benth. as a synonym. Corrick (1993) included both varieties under *P. forsythiana* Blakely (1941), while de Kok and West (2003) included them under *P. blakelyi* Joy Thomps. and Weston & de Kok (2002) included var. *mucronata* under *P. juniperina*. A more recent collection of the Yarrowyck entity (*Copeland 3245 & Croft*) was identified as *P. flexilis* Sm. during a recent revision of the genus (de Kok and West 2002).

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Herbarium collections of both *P. juniperina* and *P. flexilis* (both which are considered to be morphologically variable) were examined in this study to investigate the status of Williams' collections and their putative relationships. Since a closer morphological correlation was found with *P. flexilis*, a discussion is here included about how these specimens differ from *P. flexilis*, followed by a description of the new species *P. williamsii* I.Telford, Clugston & R.L.Barrett.

As *P. flexilis* is a sister lineage to the *P. glabra* complex, the new species described here is also likely related to the broader *P. glabra* complex. However, that group has recently been revised and the taxon we describe here is morphologically distinct (Renner *et al.* 2022).

Materials and Methods

The following description is based on examination of herbarium specimens at NE and NSW. The first author has also studied this species in the field. Type specimens of related species have been studied first-hand at MEL and NSW.

Results and discussion

The Yarrowyck specimens first identified by John Williams differ from *Pultenaea blakelyi* and *P. flexilis* based on multiple morphological characters (Table 1). In the key by Weston and de Kok (2022), specimens collected at high altitudes in the Northern Tablelands bioregion of NSW (e.g. Mount Kaputar, Torrington, Mount Yarrowyck (now Bulagaranda)) that possess incurved, ±concolorous leaves that taper to a pungent apex key out as either *P. flexilis* if one considers the leaves flat (this species includes coastal plants bearing flat, strongly discolorous leaves with rounded, mucronate apices), or *P. glabra* Benth. if one considers the leaf margin strongly incurved. However, the latter interpretation would probably only occur with immature leaves or when only considering the apical area of the leaf.

The type of *P. flexilis* is from Port Jackson (Smith 1805), and numerous near-coastal and Blue Mountains specimens match the type concept. The appropriate circumscription of *P. flexilis* remains in need of clarification, and the application of several synonymous names required rigorous assessment, but the northern tableland specimens appear to be misplaced in *P. flexilis*. Within the specimens at variance from the typical form of *P. flexilis*, specimens from Mount Yarrowyck Nature Reserve north to Mount Tingha (Fig. 1) represent a distinctive entity which we assessed against the full range of variation recognised in *P. flexilis s. lat.* and *P. blakelyi*, with data for *P. flexilis s. str.* presented in Table 1 to encourage furth comparison of populations that do not match this concept.

Table 1. Comparison of selected morphological attributes that differentiate *Pultenaea williamsii* from *P. blakelyi* and *P. flexilis s. str.*

Attribute	*P. flexilis s. str.*	*P. blakelyi*	*P. williamsii*
Stipule length (mm)	1.5–2.1	0.8–1.5	2.8–4
Leaf length (mm)	12–19	8.5–18	14.5–24
Leaf margin	flat	incurved	incurved
Leaf apex	rounded, mucronate	pungent	pungent
Calyx length (mm)	3.8–5.3	4–5.2	5.8–6.8
Standard length (mm)	6.0–8.2	5.4–7.6	8.6–10.5

Pultenaea blakelyi grows in forests east of the Great Divide, wetter than those in the Yarrowyck region, with the populations occurring near Dorrigo geographically closest to the Yarrowyck entity. The *P. juniperina* and *P. flexilis* complexes remain poorly resolved with other names, including *P. blakelyi*, variously misapplied, as indicated by numerous isolated or disjunct occurrence of each species on AVH (CHAH 2022; http://avh.ala.org.au/occurrences/search?taxa, accessed 3 May. 2022) and by Weston & de Kok (2022). New England populations may constitute several new species, of which the following is the most distinctive, and is named here as *P. williamsii*.

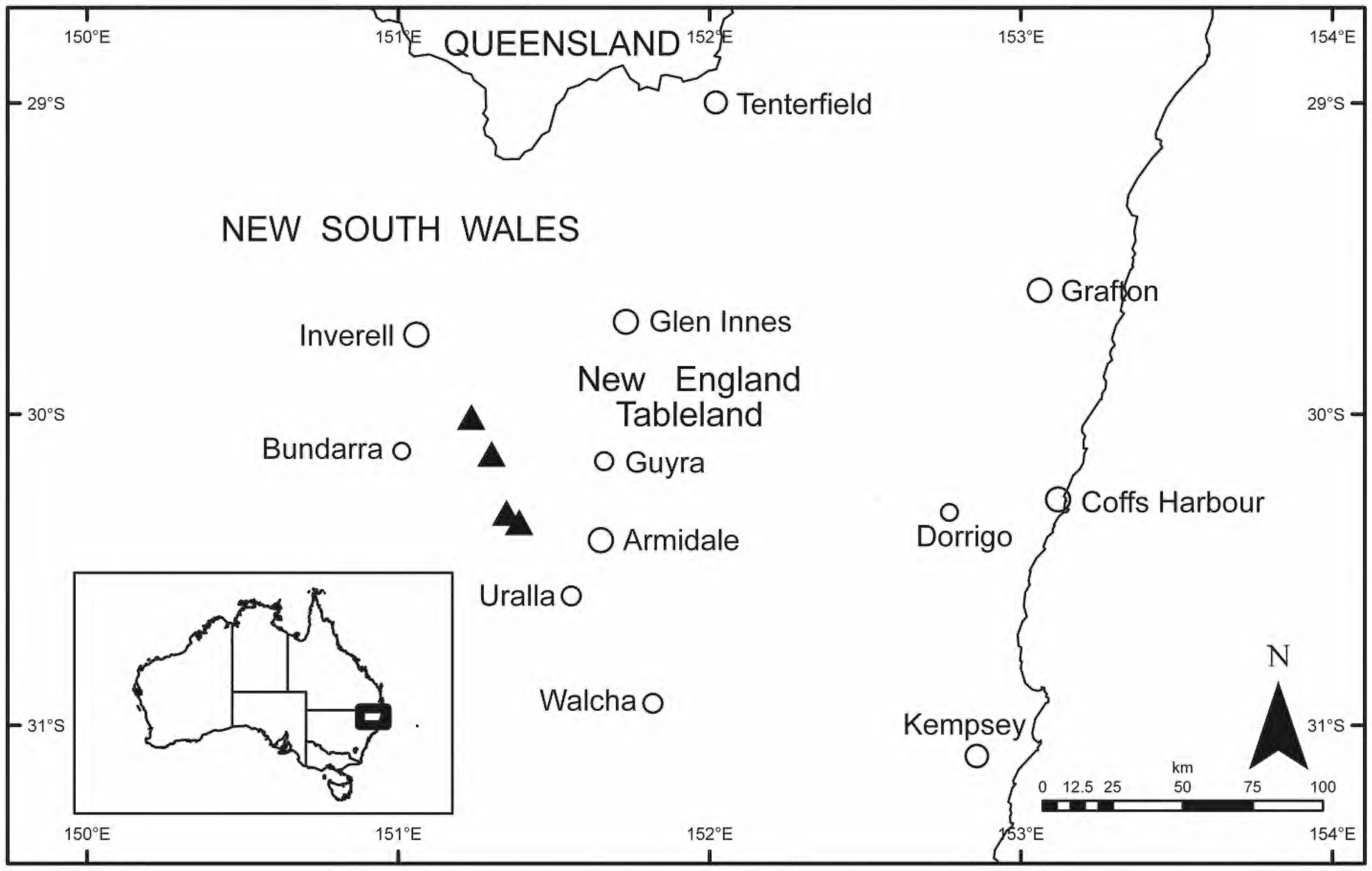

Fig. 1. Distributions of *Pultenaea williamsii* (▲).

Taxonomy

Pultenaea williamsii I.Telford, Clugston & R.L.Barrett, ***sp. nov.***

Type: NEW SOUTH WALES: Northern Tablelands: private property adjoining Indwarra Nature Reserve, c. 18 km NE of Bundarra, 2.1 km SW of Mt Tingha, 1 Nov. 2001, *L.M.Copeland 3245 & P.Croft* (holo: NE 76899; iso: CANB, *n.v.*, NSW 599837).

Erect *shrub* 0.5–3 m high, spreading to 4 m wide. *Branchlets* erect to spreading, stiff, sparsely to moderately pubescent with spreading, straight or crisped hairs to 0.6 mm long; ribbed below petioles. *Stipules* lanceolate, fused for c. half their length, 2.3–4.5 mm long, very strongly keeled, margin minutely dentate, apex spreading, acuminate, dark red-brown with paler margins. *Leaves*: petiole 0.6–1.5 mm long; lamina narrowly elliptic, discolorous, green with dense, conical or mamillose papillae on adaxial surface; brownish with scattered shortly conical papillae on abaxial surface (papillae formed by single epidermal cells); lamina 13.2–24 mm long, 1.8–3.8 mm wide, margin incurved, apex acute, rigidly and sharply mucronate, mucro 0.7–1.4 mm long. *Inflorescence* of solitary flowers borne in upper axils, appearing loosely clustered. *Flowers* with pedicels 2.2–4.6 mm long, with scattered, spreading, straight or crisped hairs to 0.4 mm long; bracteoles inserted c. 1 mm above base of calyx tube, appressed at base, lanceolate, 1.8–2.7 mm long, 0.7–0.8 mm wide, mucronate, sparsely pubescent along keeled midvein, dark red-brown with paler margins; floral stipules absent; calyx tube broadly obconic, 3.0–3.8 mm long, sparsely pubescent in upper half outside; lobes 5, subequal, the upper pair fused for c. half their length, broadly triangular, 1.8–3.5 mm long, acuminate, minutely white-fimbriate; standard petal ±circular in appearance, or obcordate when flattened and claw is visible, emarginate, 8.6–10.5 mm long including 3.0–3.8 mm claw, 7.8–10.1 mm wide, yellow; wing petals narrow-oblong, 7.1–10.5 mm long including 2.5–3.1 mm claw, 2.1–2.4 mm wide, yellow; keel petals naviculate, ±narrow-oblong in outline, 9.4–9.9 mm long including claw 2.8–3.2 mm long, 3.2–3.5 mm wide (folded), exceeding wings, mostly red, grading to yellow at the claw; stamens free, ±equal in length; filaments 7.9–8.4 mm long; anthers 0.6–0.7 mm long; ovary glabrous, 1.3–1.5 mm long; style curving almost 90° at mid-point, with long, semi-appressed hairs from lower 1/5 to upper 1/3 its length, 7.2–7.9 mm long; stigma inconspicuous, very slightly capitate. *Fruit* ovoid, compressed, asymmetrically beaked, 8.0–8.6 mm long including stylar remnant, c. 2.8 mm diam., glabrous, brown. *Seeds* compressed ovoid, c. 3 mm long, c. 1.8 mm wide, smooth, dark brown. (Figs 2, 3)

Fig. 2. Holotype of *Pultenaea williamsii* I.Telford, Clugston & R.L.Barrett (NE 76899). Photo by J.J. Bruhl.

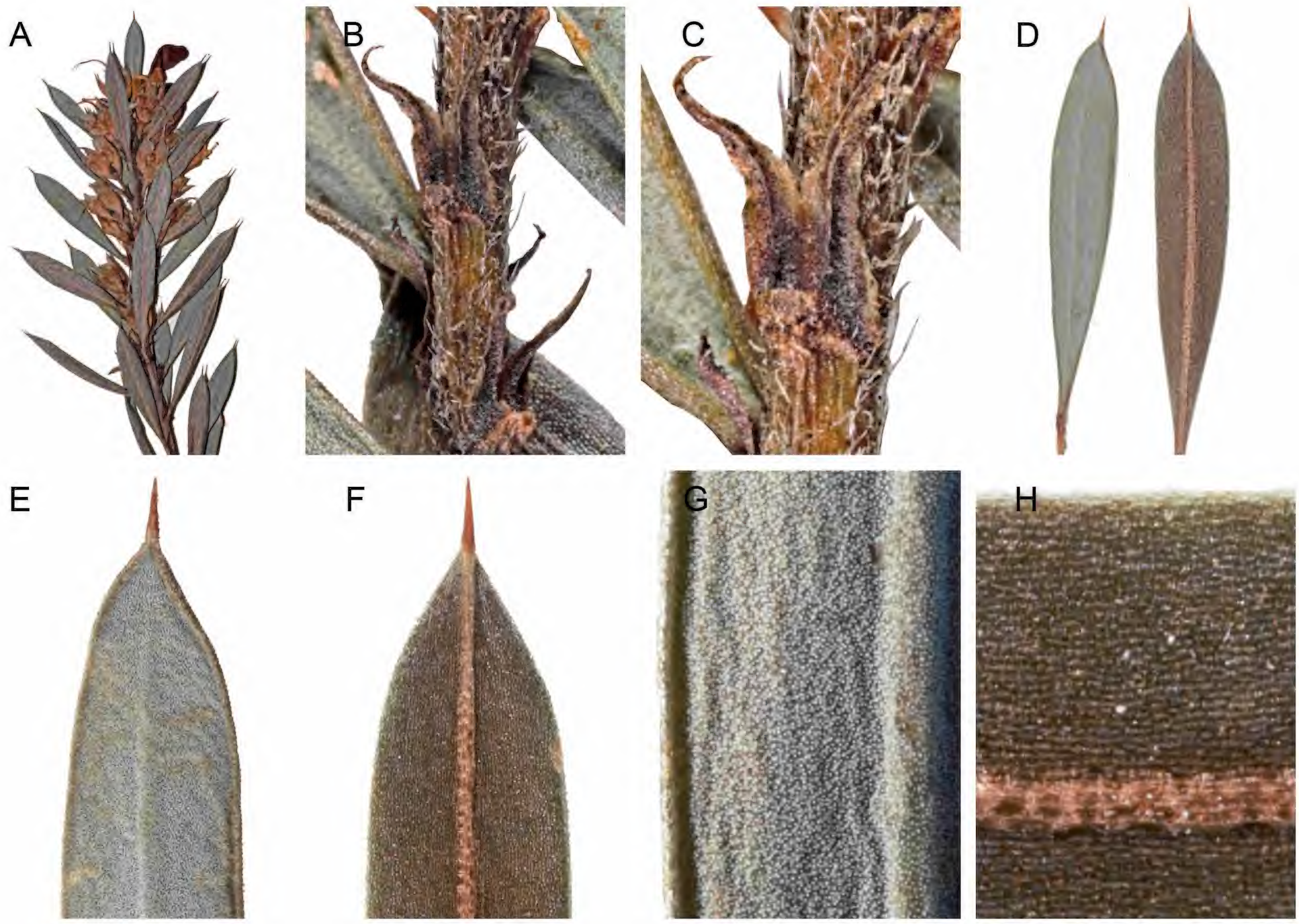

Fig. 3. Isotype of *Pultenaea williamsii* I.Telford, Clugston & R.L.Barrett (NSW 599837). A. Flowering branchlet. B, C. Stipules. D. Leaves. E. Leaf tip (adaxial surface). F. Leaf tip (abaxial surface). G. Adaxial leaf surface. H. Abaxial leaf surface. I. Adaxial calyx lobes, calyx and bracteoles. J. Abaxial calyx lobes, calyx and bracteoles. K. Lateral view of calyx and bracteole. L. Calyx partially removed to show glabrous ovary and hairy style. Photos by R.L. Barrett.

Diagnostic characters: With affinities to *Pultenaea blakelyi* and *P. flexilis*, differing in larger (14.5–24 *vs* 8.5–19 mm long), more rigidly pungent, discolorous (*vs* usually concolorous) leaves with incurved (*vs* plane to slightly incurved) margins, dense, conical papillae above and scattered shortly conical papillae below (*vs* usually not papillate), longer stipules (2.8–3.2 mm long *vs* 0.8–1.5 in *P. blakelyi*; 1.5–2.1 in *P. flexilis*), larger calyx (5.8–6.8 mm long *vs* 4–5.2 in *P. blakelyi*; 3.8–5.3 in *P. flexilis*) and larger standard (8.5–9.2 mm long *vs* 5.4–7.6 in *P. blakelyi*; 6.0–8.2 in *P. flexilis*).

Somewhat similar in appearance to *Pultenaea* sp. Genowlan Point (NSW 417813), but *P. williamsii* differs in its non-glaucous (*vs* ± glaucous), narrowly elliptic (*vs* oblanceolate) leaves, 1.8–3.8 mm wide (vs 0.6–2.1 mm wide), hairy (*vs* glabrous) pedicels and stipules attached near the base (*vs* close to the middle) of the calyx tube.

Distribution and habitat: *Pultenaea williamsii* is endemic to the New England Tableland Bioregion (Department of Agriculture, Water and the Environment 2022) on the western fall of the New England Tableland from near Tingha, NW of Guyra, to Yarrowyck, W of Armidale (Fig. 1). The species grows in *Eucalyptus andrewsii* woodland on rocky sites on granite, granodiorite and metasediments at 1100–1200 m altitude at two disjunct

locations about 75 km apart. Other associated species recorded include *Acacia buxifolia*, *Acacia lanigera*, *Acacia* sp. New England (J.B.Williams 97011), *Boronia algida*, *Boronia microphylla*, *Brachyloma daphnoides*, *Chiloglottis formicifera*, *Eucalyptus laevopinea*, *Eucalyptus malacoxylon*, *Hakea eriantha*, *Hovea graniticola*, *Leucopogon affinis*, *Lomatia silaifolia*, *Olearia ramossisima*, *Orianthera pusilla*, *Persoonia cornifolia*, *Polystichum fallax*, *Pultenaea campbellii*, *P. spinosa* and *Rytidosperma pallidum*.

Specimens examined: New South Wales: Northern Tablelands: 1 mile E of Yarrowyck, Oct. 1961, *J.B.Williams s.n.* (NE 10386, NSW 929173); Mt Yarrowyck, c. 24 km N of Uralla, 6 Dec. 2009, *D.W.Lawrence 607* (NE, NSW); Mount Yarrowyck, c. 24 km N of Uralla, 10 Jan. 2010, *D.W.Lawrence 622* (NE, NSW); c. 28 km directly WNW of Armidale, central south ridge of Mount Yarrowyck, 29 Aug. 2010, *D.W.Lawrence 725* (NE, NSW); Mt Yarrowyck, summit ridge, c. 26 km WNW of Armidale, 30 Oct. 2010, *I.R.H.Telford 13335* (NE, NSW).

Phenology: Flowering October–November; fruiting October–December.

Etymology: Honouring John Beaumont Williams (1932–2005), former lecturer in Botany, University of New England, whose passion for and knowledge of plants of north-eastern New South Wales contributed so much to our understanding of its flora.

Conservation Status: *Pultenaea williamsii* is currently known from four populations. The population on Mount Yarrowyck numbers several hundred plants along c. 500 m of the summit ridge. The size of other populations is not known, but it is noted as locally common in collection notes. For the present, the species must be regarded as 'Not Evaluated' under IUCN (2014) guidelines but a category of 'Vulnerable' is suggested following the NSW Threatened Species Conservation Act (1995) based on its restricted distribution. The species is conserved in The Basin (L.M. Copeland pers. comm.) and Balangaranda Aboriginal Area (formerly Mount Yarrowyck Nature Reserve), and probably occurs in Indwarra Nature Reserve, adjacent to a known occurrence in the same habitat, but it is yet to be collected there.

Notes: The species has been recognised at NE for some time under the informal phrase name *Pultenaea* sp. Yarrowyck (J.B.Williams NE 10386) I.Telford and some duplicates have been distributed as such.

Modification to the New South Wales Flora Online key

The key in Weston and de Kok (2022) may be modified to accommodate the new species as follows:

44 Leaves with apex straight and aristate 44A

Leaves with apex recurved and not aristate ..... **Pultenaea alea**

44A Leaves ±concolorous, with plane margins, mucro not pungent; lamina without conical papillae; stipules 1.5–2.1 mm long; calyx 3.8–5.3 mm long; standard 6.0–8.2 mm long ..... **Pultenaea flexilis**

Leaves discolorous, with incurved margins, mucro rigidly pungent; lamina with dense, conical papillae on adaxial surface and scattered shortly conical papillae on abaxial surface; stipules 2.8–3.2 mm long; calyx 5.8–6.8 mm long; standard 8.5–9.2 mm long ..... **Pultenaea williamsii**

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Machaerina ascendens (Cyperaceae), a rare new species from the far south-west of Western Australia, and a new combination for *Schoenus abbreviatus* Nees

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Abstract

We here describe *Machaerina ascendens* R.L.Barrett & K.L.Wilson as a new species from swamps within forests in the far south-west of Western Australia. The new species is readily identifiable by its scrambling habit and compressed, multi-noded culms, features which separate it from all other Australian species. The clearly distichous glumes, few hypogynous scales fused at the base into a ring and prominently stipitate nutlets are also unusual features in *Machaerina* Vahl. *Machaerina ascendens* is highly range-restricted by its specific habitat and appears to qualify for listing as Endangered. Study of all names applicable to the current concept of *Machaerina* revealed an earlier name for the eastern Australian species *Machaerina nuda* (Steud.) J.Kern, and a new combination is provided here for *Schoenus abbreviatus* Nees as *Machaerina abbreviata* (Nees) R.L.Barrett & K.L.Wilson.

Keywords: Cyperaceae; Australia; Systematics; Taxonomy; Rare species

Introduction

Machaerina Vahl is a genus of at least 55 named species (Larridon *et al.* 2021). The genus is now placed in Tribe Schoeneae, subtribe Lepidospermatinae R.L.Barrett, along with *Lepidosperma* Labill., *Neesenbeckia* Levyns and *Netrostylis* R.L.Barrett, J.J.Bruhl & K.L.Wilson (see Levyns 1947; Barrett & Wilson 2012; Barrett *et al.* 2021a; Larridon *et al.* 2021). The genera *Baumea* Gaudich., *Vincentia* Gaudich., and *Chapelliera* Nees are here included in *Machaerina* based on a combination of morphological characters and phylogenetic data (Bruhl 1995; Strong 1997; Muasya *et al.* 2009; Barrett & Wilson 2012; Bruhl *et al.* 2012; Viljoen *et al.* 2013; Wilson 2015; Browning & Goetghebeur 2017; Larridon *et al.* 2018a, 2018 b, 2021). This re-circumscription coincides with a number of generic realignments in tribe Schoeneae in order to create monophyletic genera (Zhang *et al.* 2007; Bruhl *et al.* 2012; Slingsby *et al.* 2014; Musili *et al.* 2016; Barrett *et al.* 2017; 2019; 2020, 2021a, 2021b, 2021c; Elliott & Muasya 2017, 2019, 2020; Elliott *et. al.* 2019; 2021; Semmouri *et al.* 2019; Larridon *et al.* 2021).

A previously unnamed species from the far south-west of Western Australia is here described as *Machaerina ascendens* R.L.Barrett & K.L.Wilson. The species was given a phrase name at PERTH in 2002 by M. Hislop, who recognised its affinities, as *Baumea* sp. Blackwood (R. Davis 7681). This name was later updated to *Machaerina*

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sp. Blackwood (R. Davis 7681) (Western Australian herbarium 1998–) to reflect more recent generic concepts (see Larridon *et al.* 2021). The new species is distinctive for its scrambling habit, compressed, multi-noded culms, clearly distichous glumes, with few hypogynous scales fused at the base into a ring, and prominently stipitate nutlets.

A previously overlooked name, *Schoenus abbreviatus* Nees is recognised as an earlier name for *Machaerina nuda* (Steud.) J.Kern, and a new combination is provided here as *Machaerina abbreviata* (Nees) R.L.Barrett & K.L.Wilson.

Methods

The description of *Machaerina ascendens* is based on field studies by both authors and on examination of specimens held at NSW and PERTH. The format of the description is modified from Wilson (1980). Cited specimens have been seen by one or both authors apart from those indicated as being seen only as images.

Taxonomy

Machaerina ascendens R.L.Barrett & K.L.Wilson, *sp. nov.*

Type: Western Australia: [precise locality withheld] S of Blackwood River, 27 Oct. 2008, *R.L.Barrett & K.L.Wilson RLB 5333* (holo: PERTH 09457526; iso: CANB, K, MEL, NE, NSW, PERTH 09457569, US).

Baumea sp. Blackwood (R. Davis 7681), Western Australian Herbarium (1998–) *FloraBase: the Western Australian Flora*. https://florabase.dpaw.wa.gov.au/ (accessed Dec. 2016)

Machaerina sp. Blackwood (R. Davis 7681), Western Australian Herbarium (1998–) *FloraBase: the Western Australian Flora*. https://florabase.dpaw.wa.gov.au/ (accessed Feb. 2022)

Scrambling or sprawling perennial forming dense clumps sprawling through shrubs (supported by surrounding vegetation), rhizome ± absent, roots short, fibrous. Culms erect to spreading, green or yellow-green, strongly compressed, biconvex, margins finely retrorse-scabrous, 5- to many-noded, 90–180 cm tall, 2.0–6.5 mm wide. Leaves cauline, equitant, compressed, biconvex, 22–45 cm long, 3–7.2 mm wide, somewhat soft- to tough-textured, margins finely retrorse-scabrous, shorter than culms and inflorescence; sheaths green or yellowish; lowest leaves sometimes reduced to sheaths. Inflorescence bracts green, or yellowish at the base, flat, basal bract much longer than lowest branch of inflorescence, bracts reducing in size along the inflorescence, 3–28 cm long. Inflorescence loosely paniculiform, (8.5–)21–40 cm long, with 2–6 branchlets, branches erect, finely sulcate, margins finely retrorse-scabrous; rachis elongated between lowest and upper branches, sulcate, scabrous on margins, 5–12 cm long; basal branchlet 7–15 cm long, with 3–11 loosely clustered to spreading spikelets. Spikelets 9–12 mm long, solitary or loosely clustered, with 1 or 2 fertile flowers in the upper glumes (lower flower when present functionally male), glumes distichous, usually prominently spreading at maturity, persistent. Glumes (4) 6, linear-lanceolate, long-acuminate, 7.6–9.5 mm long, green along the keel with red-brown margins, with (1 or) 3 prominent nerves. Stamens 3; filaments (3.5–)6.1–8.2 mm long, anthers 3.9–4.9 mm long, and an apical appendage 0.8–1.1 mm long. Style 3-fid, base 3.3–4.4 mm long, glabrous, somewhat compressed to slightly angular towards the base, branches 3.5–5.3 mm long, finely papillose. Hypogynous scales present, fused in a ring at the base with 1–3 short ± triangular scales protruding from the ring up to 0.3 mm long. Nutlet prominently stipitate, ovoid to ellipsoid, pale brown to mid-brown, glabrous, 2.4–2.8 mm long, 1.6–1.8 mm wide, strongly 3-costate, sides convex between the costae; stipitate base 0.8–1.2 mm long, ± cylindrical; style-base fused to nutlet apex distinct, ± shortly pyramidal, slightly paler in colour, 0.4–0.5 mm long. (Fig. 1)

Diagnostic characters: Readily distinguished by its scrambling habit and compressed, multi-noded culms, features which separate it from all other Australian species. The clearly distichous glumes, few hypogynous scales fused at the base forming a ring, and prominently stipitate nutlets are also unusual features in *Machaerina*.

Other specimens examined: WESTERN AUSTRALIA [precise localities withheld for conservation reasons]: [N of Karridale], 23 Sept. 1992, *A.R.Annels ARA 2488* (PERTH); [NE of Nillup], 16 Nov. 1992, *A.R.Annels ARA 2990* (PERTH); [NE of Nillup], 26 Aug. 1996, *A.R.Annels, R.Hearn & T.D.Macfarlane ARA 5761* (PERTH); [near Blackwood River], 9 Mar. 2006, *T.Brown BNC 901* (PERTH); [NE of Nillup], 21 Oct. 1998, *R.Davis 7681* (PERTH); [near Gingilup Swamp], 31 Jan. 1997, *C.Day & D.Bright B 120.12* (PERTH); [near] Rosa Brook, 27 Aug. 2007, *M.Morley 141* (PERTH); [near] Nillup, 30 Oct. 1948, *R.D.Royce 3020* (PERTH 02333007); [NE of Nillup], 20 Nov. 2001, *C.Tauss 1-116; 1-117; 1-118* (PERTH); [NE of Nillup], 20 Nov. 2001, *C.Tauss 1-122* (PERTH); SE of Margaret River, 1 Sept. 1992, *G.Wardell-Johnson GWJ4* (PERTH 02657597); [NE of Nillup], 18 Nov. 1994, *K.L.Wilson & K.Frank 8945* (NSW).

Fig. 1. *Machaerina ascendens*. A. Herbarium sheet. B. Inflorescence. C. Infructescence. D. Fruiting spikelets. Vouchers: A, B: *G.Wardell-Johnson GWD14*; C, D: *R.D.Royce 3020* (both PERTH). Photographs by R.L.Barrett.

Distribution: Occurs in the Blackwood River area in the Warren Bioregion in south-west of Western Australia where it is considered to be endemic. Most populations occur in swamps associated with the Blackwood River, with two outlying populations associated with Rosa Brook and Gingilup Swamps.

Habitat: Grows in water or waterlogged soil towards the edge of swamps that are waterlogged and boggy for most or all of the year, in peaty, sandy, or clay soils. These swamps are unusual for their consistently high groundwater tables that are low in salinity and nutrients, constantly anoxic, and often highly acidic (Tauss 2004). Recorded in association with *Actinotus laxus*, *Astartea* sp., *Beaufortia sparsa*, *Boronia crenulata*, *Boronia molloyae*, *Boronia tenuior*, *Callistachys lanceolata*, *Centrolepis fascicularis*, *Chorizandra cymbaria*, *Empodisma gracillimum*, *Eutaxia exilis*, *Gonocarpus diffusus*, *Gymnoschoenus anceps*, *Hakea varia*, *Homalospermum*

firmum, *Hypolaena exsulca*, *Juncus pallidus*, *Juncus planifolius*, *Lepidosperma tetraquetrum*, *Lepidosperma* sp. Blackwood River (R.Davis 7696), *Leptocarpus coangustatus*, *Leptocarpus scariosus*, *Leptocarpus tenax*, *Leptomeria ellytes*, *Lobelia anceps*, *Loxocarya cinerea*, *Machaerina acuta*, *Machaerina riparia*, *Machaerina rubiginosa*, *Machaerina vaginalis*, *Melaleuca incana*, *Morelotia octandra*, *Patersonia occidentalis*, *Pseudolycopodiella serpentina*, *Pteridium esculentum*, *Reedia spathacea*, *Rhadinothamnus anceps*, *Sphenotoma capitatus*, *Sphaerolobium drummondii*, *Sphaerolobium hygrophilum*, *Sphaerolobium medium*, *Sporodanthus rivularis*, *Stylidium nymphaeum*, *Stylidium scandens*, *Stylidium thryonides*, *Taraxis grossa*, *Taxandria juniperina*, *Taxandria linearifolia*, *Taxandria parviceps*, *Triglochin* sp., *Utricularia tenella*, *Xyris indivisa* and *Xyris lacera*.

Phenology: Flowers recorded for August–October. Fruit recorded for October–November.

Conservation status: Likely to be endangered. Nine extant populations are known, most of which occur in an area about 10 km across near the Blackwood River, to the north-east of Nillup, with three disjunct populations between 15 and 25 km away. The area of occurrence is about 350 km^2 and the area of occupancy is about 20 ha (0.25 km^2). An assessment of conservation status using IUCN (2002) criteria based on known distribution and threats suggests it should be listed as Endangered (B1a,b(iii),B2a,b(iii)).

Occurs in Blackwood River National Park, Bramley National Park and Gingilup Swamps Nature Reserve. The species occurs in habitats that are threatened by frequent fire as the swamps are formed along drainage lines surrounded by dry, fire-prone forest. The collection notes for *R.D.Royce 3020* record grazing by both cattle and kangaroos. Feral pigs are noted to be significantly impacting these habitats and may be directly threatening some populations (Tauss 2004). As consistently high water tables are a key part of these habitats, any localised groundwater extraction may have a significant effect on populations (Tauss 2004). Conservation Codes for Western Australian Flora: Threatened recommended, but this species should be assessed to determine if it qualifies for listing as Critically Endangered in Western Australia under IUCN criteria as it faces similar threats to the rare sedge *Reedia spathacea* F.Muell., which is known from 27 populations, co-occurring with *M. ascendens* in some of them, and is currently listed as Critically Endangered. *M. ascendens* is considered to have an even more restricted distribution and, as a far less robust species lacking a distinct rhizome, is probably at greater risk than *R. spathacea* from the same set of threats.

Machaerina ascendens is found in association with frogs in the genus *Geocrinia* Blake, so the habitats have been relatively well-studied (e.g. Wardell-Johnson & Roberts 1993). Two species, *Geocrinia alba* and *G. vitellina*, are listed as Critically Endangered.

Vernacular name: The vernacular name of Blackwood Twigrush is recommended.

Etymology: From the Latin *ascendens* (ascending or climbing) in reference to the unusual habit of the species, scrambling and climbing over surrounding vegetation.

Affinities: There are no morphologically similar species in Australia. Unpublished molecular phylogenetic data (based on only partial sampling of the genus) places this species as sister to *Machaerina angustifolia* (Gaudich.) T.Koyama from Hawaii (Bruhl *et al*. 2012). *Machaerina angustifolia* differs in having nodeless erect culms arranged in a tussock (common in many *Machaerina* spp.), broader leaves (to *c*. 25 mm wide), longer inflorescences (30–50 cm long), perianth apparently absent, and not or slightly stipitate nutlets (Koyama 1999).

Notes: The habit of *Machaerina ascendens* is shorter and more compact when found growing in open locations, with most plants being lax and sprawling over surrounding vegetation. The lax habit and somewhat unusual floral features led to early speculation that this species may belong to the genus *Scleria* P.J.Bergius, having superficial similarities to sprawling and climbing species from Central and South America such as *Scleria bracteata* Cav. (Core 1936). While collections of this species were already held at PERTH, Wheeler and Graham (2002) did not treat this taxon as there was uncertainty over its generic placement.

Machaerina abbreviata (Nees) R.L.Barrett & K.L.Wilson, *comb. nov*.

Basionym: *Schoenus abbreviatus* Nees, *Fl. oder Allg. Bot. Zeit.* 11: 292 (1828).

Lectotype (here designated): New South Wales: Sydney District, 1823, *F.W.Sieber Agrost. No. 19* (P 00585281). *Isolectotypes*: G 00195262, G 00195263, G 00195264, H 1224937 (image), L 0042667 (image), L 0042668 (image), MEL 2292591, MEL 2297528, W 1889-0265769 (image).

Schoenus nudus Steud., *Syn. Pl. Glumac.* 2: 165 (1855). *Cladium nudum* (Steud.) Boeckeler, *Linnaea* 38: 236 (1874). *Mariscus nudus* (Steud.) Kuntze, *Revis. Gen. Pl.* 2: 755 (1891). *Machaerina nuda* (Steud.) J.Kern, *Acta Bot. Neerl.* 8: 266 (1959). *Baumea nuda* (Steud.) S.T.Blake, *Contrib. Queensl. Herb*. 8: 28 (1969).

Type: New South Wales: Sydney District, 1823, *F.W.Sieber Agrost. No. 19* (*holo*: P 00585281; *iso*: G 00195262, G 00195263, G 00195264, H 1224937 (image), L 0042667 (image), L 0042668 (image), MEL 2292591, MEL 2297528, W 1889-0265769 (image).

Typification: While Nees (1828) cited only the collection *Sieber Agrost. No. 19* when describing *Schoenus abbreviatus*, it is not clear which material of that number was available to him – none of the sheets that we have seen has been annotated by him. We designate the sheet at P as lectotype as this is also the holotype of *Schoenus nudus*. We accept the P specimen as a holotype of *Schoenus nudus* as it is the only sheet of this species annotated 'Herbarium Steudel' and as far as we can determine, the only sheet examined by Steudel in preparing the description.

Notes: In naming *Schoenus nudus*, Steudel (1855) appears to have overlooked that Nees (1828) had used the same Sieber collection when describing *Schoenus abbreviatus,* which is therefore the earlier name for the taxon. The publication of Nees (1828) lists taxa by Sieber's *Agrostotheca* numbers, which are readily misinterpreted as species order numbers specific to the publication, rather than a reference to a specific *Agrostotheca* collection by Sieber. The existence and application of the name *Schoenus abbreviatus* has been ignored by later botanists, despite *Sieber Agrost. No. 19* being cited in the protologue. It was only when material at MEL (MEL 2297528) was examined in 2019, with the name *Schoenus abbreviatus* on the sheet, that we realised that the application of Nees' name had been overlooked. Only the specimen at H has previously been annotated as being a type for both *Schoenus* names, but that annotation was recent, in 2011.

This species is similar in appearance to *M. gunnii*, but the plant is generally smaller, so the epithet '*abbreviatus*' is appropriate. The leaves greatly exceed the culms (*vs* not or only slightly exceeding them in *M. gunnii*), the culms are more slender (0.5 *vs* 0.7–1.5 mm diam.), lax and smooth (*vs* erect and often scaberulous), and the nutlets are only 2.0–2.3 (*vs* 2.5–3.5) mm long (see Wilson 1993 for a full description).

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Grevillea gilmourii Olde and *G. milleriana* Olde (Proteaceae: Grevilleoideae: Hakeinae), two species newly described from New South Wales

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Abstract

Grevillea gilmourii Olde and *G. milleriana* Olde, two species new to science, are described. They are putative members of the *Aspleniifolia/Hookeriana* Subgroup of the *Grevillea Pteridifolia* Group. *Grevillea gilmourii* is separated from *G. macleayana* (McGill) Olde & Marriott where it had previously been treated as the '*Deua form*', a geographically disjunct, divided-leaf variant. The separate formal recognition of *G. gilmourii* here necessitates a revised delineation of *G. macleayana* to restrict it to populations with undivided leaves only, incorporating recent clarification to terminology in relation to leaf lobing. *Grevillea milleriana* is a recent discovery from the Maddens Plains area, south of Sydney. Known from a single plant, its recognition as a biological species rather than as a self-sown hybrid is discussed. All three species are linked morphologically and historically to the Victorian species *G. barklyana* F.Muell. ex Benth., which remains taxonomically unaltered from recent treatments. For the sake of convenience, all four species (*G. barklyana, G. macleayana, G. gilmourii* and *G. milleriana*) are grouped informally into an alliance, the *Grevillea barklyana* alliance, for which diagnostic characters are outlined and two identification keys are given. Both newly described species have divided leaves and are known from only small populations. Conservation recommendations are provided for both new species.

Introduction

Makinson (2000a) established the *Grevillea Pteridifolia* Group which corresponds broadly to Groups 31, 32, 33 and 35 *sensu* Olde and Marriott (1994). The *Grevillea Pteridifolia* Group was divided informally into 6 Subgroups, one of which was termed the *Aspleniifolia/Hookeriana* Subgroup. Forty-seven species in that Subgroup were included by Olde and Marriott (1994: 216–220) in their Group 35, although that number has subsequently increased to 54. All members of the *Aspleniifolia/Hookeriana* Subgroup have irregular, secund inflorescences, the abaxial surface of the perianth completely glabrous and follicles with red or purple-blotched exocarps. The four species recognised here, *G. barklyana, G. macleayana, G. gilmourii* and *G. milleriana*, appear to be more closely related to each other than to other species in the group and together form a subset of the *Aspleniifolia/Hookeriana* Subgroup, here termed for convenience the '*Grevillea barklyana* alliance'. This

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alliance of species is closely linked to *G. laurifolia* Sieb. ex Spreng., *G. longifolia* R.Br. and *G. aspleniifolia* Knight but can be differentiated by the following combination of features:

- leaves broad (mostly ≥ 20 mm wide), elliptic, pinnatifid or with margins entire, the under-surface densely hairy except the midvein;
- inflorescences erect;
- pistils ≥ 18 mm long, the ovary stipitate, densely hairy;
- styles pink, glabrous except at base just above the ovary;
- style-end green or yellow.

Ferdinand Mueller (1860–61: 14) first mentioned his discovery of *Grevillea barklyana* in his annual report to the Victorian Parliament. 'On my return to Melbourne I visited the Upper Tarwan, availing myself of a track formed by Mr. Devine's prospecting party; the tall *Grevillea Barklyana* (sic) was discovered on this last occasion.' Sir Henry Barkly, Toorak, then the Governor of Victoria, was noted (Mueller 1860–61: 3) in the same report as one of numerous donors to the Melbourne Botanic Gardens. It is somewhat surprising, given regular publication of new species in his *Fragmenta Phytographiae Australiae*, that Mueller neither described nor again mentioned this species until 1871, by which time Bentham (1870: 436–7) had published a description in *Flora Australiensis* based on Mueller's collection, a duplicate of which he had selflessly remitted to Bentham sometime in 1870. Mueller (1871: 133) simply referred to it, (and in Latin), as a 'shrub attaining a height of 12 feet'.

The next appearance of this 'species' came when flowering specimens of '*G. barklyana*' collected by J.H. Maiden at Jervis Bay, New South Wales in July 1892 were displayed at the November meeting of the Linnean Society of New South Wales. Maiden showed them as 'new' for New South Wales, 'hitherto recorded only from Gippsland' (Maiden 1892: 404). However, according to correspondence cited by Olde (2005), Maiden was indeed well aware that the plant he collected was a new species and urged Mueller, with whom he corresponded on the matter, to name it after the recently deceased patron of science Sir William Macleay, M.P. However, the proposed taxonomic treatment lapsed after Mueller died in 1896 and Maiden did not progress the matter. Willis (1972) continued to recognise the Jervis Bay plants as a form of *G. barklyana*. Formal taxonomic recognition only eventuated when McGillivray (1986: 2) named it as *G. barklyana* subsp. *macleayana* McGill. In the diagnosis, he distinguished it from subsp. *barklyana* by its persistent floral [common] bracts, and its subvillous ovary.

In a fuller treatment of *G. barklyana*, McGillivray and Makinson (1993: 56) further elaborated differences between the two subspecies in their key which states, among other things, that subsp. *macleayana* has 'leaves simple'. In a subsequent note on variation, it was stated that a collection from Diamond Creek, Deua National Park with 'some divided leaves adjacent to the inflorescences' 'belongs to or is very closely allied to subsp. *macleayana*' because of other shared floral features.

Olde and Marriott (1994: 185) regarded the stated floral differences between the subspecies as sufficient to enable recognition of *G. macleayana* as specifically distinct, while at the same time incorrectly interpreting embayments and some strong margin crenulation as leaf lobing, confounding it to some extent with *G. barklyana*, which has leaves with numerically more lobes. The species ranking was subsequently accepted in the *Flora of Australia* treatment (Makinson 2000a).

In their treatment of *G. macleayana*, Olde and Marriott (1995b: 9) recognised three forms, a '*Coastal form*', a '*Woolly form*' and a '*Deua form*', all of which were stated to have various degrees of leaf lobing. More recently, leaf lobes have been more critically interpreted by Olde (2015: 99), with input unacknowledged until now, from Dr Peter Weston (NSW). 'A leaf lobe is usually defined simply as part of a leaf enclosed by embayed or angular incisions in the margin. However, it is more strictly interpreted here as formed around a lateral or secondary vein that terminates at the margin in a short excurrent spine or mucro. Marginal teeth are short lobes formed from a higher order lateral vein or vein subsidiary to the intramarginal vein, but with a similar terminus. In a situation where both lobes and teeth are present, Crisp and Weston (1993, p. 56) have suggested that 'the relative prominence of the vein leading to the lobe or tooth' be used to differentiate them. Leaf-margin sinuation or crenulation differs in its lack of venation and is not therefore treated as a form of division.'

When we accept this definition, then neither the *Coastal form* (typical form), nor the *Woolly form* of *G. macleayana sensu* Olde and Marriott (1994) have lobed leaves. This sharpens and simplifies the conceptual distinction between populations with entire leaves only (all here included now in *G. macleayana*) and those sometimes with some divided leaves (here circumscribed as three separate distinct species: *G. barklyana, G. gilmourii,* and *G. milleriana*).

Subsequent collections from the Deua population at Diamond Creek, which is in steep country *c.* 100 km south-west from the nearest other populations of *G. macleayana*, confirm the other noted differences between the taxa outlined by McGillivray and Makinson (1993). These collections have been made by N. Taws *et al.* (NSW383047, NSW943097, NSW943098) and J. Knight *et al.* for the Eurobodalla Botanic Garden. This supports the decision taken here to separately recognise the '*Deua form*' as a rare distinct species not only with its own distinctive morphology, but also different habitat and soil preference. Removing *G. gilmourii* from the previous circumscription of *G. macleayana* requires redefinition of the latter species with more concise morphological and ecological boundaries.

Grevillea milleriana represents a recent discovery known from only a single plant. Although a small population is inferred from previous anecdotal information, it has claims to being Australia's rarest *Grevillea* species. It was first included notionally in *G. macleayana* as a geographically disjunct extension of range (*c.* 110 km from Nowra at the northern end of the distribution). However, its divided leaves and other characters distinguish it morphologically and its preference for dense vegetation in upland swamp heath differentiate it ecologically. It is therefore affirmed here as specifically distinct.

The four species circumscribed here in the *Grevillea barklyana* alliance can be separated morphologically based on the features presented in Table 1 and comparative illustrations of styles and inflorescences represented in Figure 1.

Table 1. A comparison of morphological features of species in the *Grevillea barklyana* alliance.

	G. barklyana	***G. macleayana***	***G. gilmourii***	***G. milleriana***
HABIT	small tree to 8 m	shrub (0.3–)2–3(–4) m	small tree to 7 m	low shrub to 0.5 m
LEAVES	lobed and entire	entire	lobed and entire	lobed and entire
length	(4.5–)10–30 cm	4–15 cm	7.5–19.2 cm	5–8.5 cm
lobes	triangular	absent	obovate to narrow-triangular	broadly triangular
lobe number	0–11	0	0–6	0–8
abaxial surface	minutely velutinous	curly tomentose	curly tomentose	sericeous
FLORAL RHACHIS length	50–100 mm	25–45 mm	25–45 mm	40–50 mm
COMMON BRACTS	oblong ovate–angularly ovate	depressed ovate–triangular	ovate	ovate
length	2.5–3 mm	0.8–2.3 mm	1.8–2.5 mm	2–2.5 mm
persistence	caducous before anthesis of any flowers	persistent to anthesis	persistent to anthesis	persistent at or just before anthesis
PEDICEL length	1.75–2 mm	1.5–2.5 mm	1–1.5 mm long	3.25–3.5 mm
indumentum	white-sericeous	white-tomentose to villous	white-tomentose to pubescent	white-sericeous with some coloured hairs
NECTARY	inconspicuous	inconspicuous	inconspicuous	prominent
PISTIL length	18.5–25 mm	22–28.5 mm	22–23 mm	18–19 mm
GYNOPHORE length	0.6–2 mm	2–2.5(–3) mm	1.5 mm	1–1.25 mm
indumentum	sericeous	tomentose–sub-villous	tomentose–sub-villous	sericeous
POLLEN-PRESENTER at anthesis	green	green	green soon yellow	yellow
shape	subconical	flat to broadly convex	flat to broadly convex	subconical
PERIANTH LIMB	fawn brown-sericeous	white-tomentose	white-tomentose	rusty-sericeous
POLLEN at anthesis	pale pink	white or pale pink to translucent	dark maroon-purple	yellow
ANTHER length	1 mm	1.2 mm	1–1.2 mm	0.5 mm

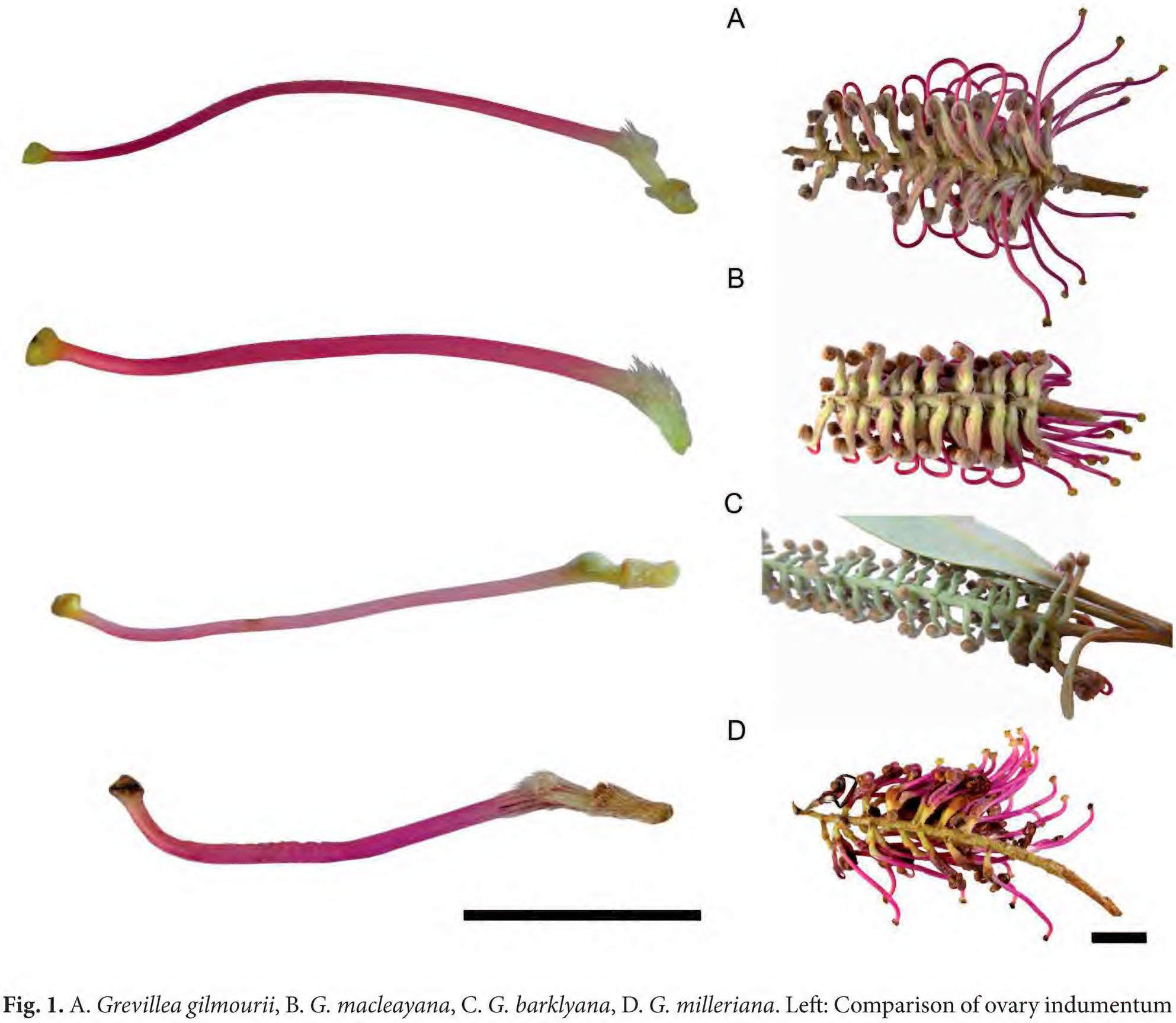

Fig. 1. A. *Grevillea gilmourii*, B. *G. macleayana*, C. *G. barklyana*, D. *G. milleriana*. Left: Comparison of ovary indumentum and style. Right: Comparison of conflorescence from below showing bract delapsus. Composite and images by M. Noake.

Key to species in the *Grevillea barklyana* alliance and some closely related species (modified from Olde and Marriott 1994: 219–220)

59 Leaf under-surface tomentose with hairs chaotically oriented, curled or wavy, semi-appressed or spreading 60

60 Most leaves ≤ 15 mm wide ..... **G. aspleniifolia**

60: Most leaves ≥ 20 mm wide 61

61 Ovary sericeous; all common bracts caducous before anthesis of any flowers in the raceme; small tree to 8 m with up to 11 triangular lobes (Vic) ..... **G. barklyana**

61: Ovary pubescent-tomentose; common bracts persistent at anthesis; plants prostrate to small trees 61A

61A All leaves simple and entire; habit of plant semi-prostrate to shrubby (NSW) ..... **G. macleayana**

61A: Some or all leaves divided; habit of plants a small tree (NSW) ..... **G. gilmourii**

59: Leaf under-surface sericeous with hairs mutually aligned, straight, appressed 62

62 All leaves simple and entire 63

63 Most leaves ≥ 20 mm wide; habit prostrate (NSW) ..... **G. laurifolia**

63: Most leaves < 12 mm wide; habit shrubby (NSW) ..... **G. longifolia**

62: Some or all leaves divided or toothed 63A

63A Common bracts 2–2.5 mm long, persistent at anthesis; pedicels > 3 mm long; pistils 18–19 mm long; most or all leaves <8.5 cm long; low-growing shrub <60 cm high (NSW) ..... **G. milleriana**

63A: Common bracts *c.* 1 mm long; caducous; pedicels 1.5–3 mm long; pistils 21–24 mm long; most or all leaves > 12 cm long; shrub 1.5–3 m high (NSW) ..... **G. longifolia**

Alternative key to the *Grevillea barklyana* alliance

1 Abaxial surface of leaves sericeous 2

2 All leaves simple and entire; styles red or black-red; habit of plant prostrate..... **G. laurifolia**

2: Some or all leaves toothed or shallowly lobed; styles pink; habit of plant low-growing but not prostrate..... **G. milleriana**

1: Abaxial surface of leaves tomentose 3

3 All leaves simple and entire; habit a decumbent to spreading shrub..... **G. macleayana**

3: Some or all leaves divided; habit a tree-like shrub 4–10 m high 4

4 Common bracts 1.8–2.5 mm long, mostly persistent at anthesis; hairs on ovary ascending to spreading; leaves 10–20 cm long, with 0–6 lobes; pollen dark maroon-purple (NSW) ..... **G. gilmourii**

4: Common bracts 2.5–3 mm long, all caducous before anthesis of any flowers in the raceme; hairs on ovary tightly appressed; leaves 12–30 cm long with 0–11 lobes; pollen pale pink (Vic)..... **G. barklyana**

Taxonomy and Nomenclature

1. ***Grevillea macleayana*** (McGill.) Olde & Marriott, *The Grevillea Book* 1: 185 (1994e). *Grevillea barklyana* subsp. *macleayana* McGill., *New Names in Grevillea*: 2 (1986). *Hakea macleayana* (McGill.) Christenh. & Byng, *Global Flora* 4: 85 (2018).

Type: New South Wales: 0.3 miles [0.5 km] E. of Bream Beach, *R. Coveny 3777*, 14 Oct 1971 (holo: NSW 544140; iso: A 00589619).

Seedlings not seen. *Mature plants* spreading, seed-obligate, self-compatible, non-lignotuberous *shrubs* usually 1.5–2.5 m high, 1.5–5 m wide, usually bushy, rarely almost prostrate and 0.3 m high, 2–3 m wide or decumbent to 0.5 m high, 1 m wide, occasionally a sub-arborescent to 4 m tall, 2–3 m wide. *Branchlets* angular in cross-section, subglabrous, reddish or overlain by a white-tomentose evanescent indumentum often with brown striations. *New growth* bronze pink. *Adult leaves* dorsiventral, simple, (1–)4–13(–15) cm long, (10–)15–45 mm wide, ascending to spreading, not crowded (internodes to 100 mm long), petiolate, ovate to elliptic or oblong-elliptic; *petioles* 5–10 mm long; *leaf base* cuneate; *leaf apex* acute to obtuse, mucronate, the mucro decurved, non-pungent; *leaf margins* entire, flat or slightly recurved, often sinuous to crenulate; *venation* brochidodromous; *adaxial surface* glabrous or nearly so, dull, the midvein discolorous, conspicuous, impressed; *lateral veins* and *intramarginal veins* similar; *lateral veins* evident but narrower, widely angled at *c.* 60–70° to midvein; *edge-vein* sometimes evident, not enlarged, glabrous; *abaxial surface* densely white-tomentose except the prominently raised midvein greenish, subglabrous, the secondary venation and reticulum also raised but densely hairy; *texture* coriaceous. *Conflorescences* (25–)35–50 mm long, 25–30 mm wide, terminal or sub-terminal, leaf-opposed, erect, unbranched, acropetal, conical-secund to oblong-secund; *conflorescence buds* cylindrical to narrowly ovoid, pedunculate; *peduncles* 5–10 mm long, brown–black- or reddish-tomentose; *floral rachises* 25–45 mm long, 1.5 mm thick, white or brown, discolorous, sericeous-tomentose, with an apical flowerless extension *c.* 3 mm long; *common bracts* (0.8–)1.2–1.8(–2.3) mm long, 1.5–1.6 mm wide, ovate, concavo-convex, tomentose outside, glabrous inside or a few hairs towards the tip, most persistent to anthesis, a solitary bract subtending the proximal flower pair up to 10 mm long, leaf-like. *Flower colour*: perianth pinkish white outside, pale pink inside; limb white or sometimes brownish in the distal half; style pale or dark pink; pollen-presenter green to yellow. *Flowers* zygomorphic, inodorous, nectariferous, acroscopic; *pedicels* 1.5–2.5 mm long, 1.2 mm wide, white-tomentose to tomentose-villous; *torus* 1–1.5 mm across, transverse; *nectary* semi-annular, rising *c.* 0.1 mm above the toral rim, the margin uneven to minutely toothed; *pistils* 22–25(–28.5) mm long; *gynophore* 2–2.5(–3) mm long, tomentose-villous; *ovary* tomentose to sub-villous, prominent ventrally; *style* glabrous except for ascending hairs at base above ovary, undulate, strongly retrorse after anthesis and almost parallel to the rachis; *style-end* abruptly

divergent from style, unguiform; *pollen-presenter* 1.2 mm long, 1.2 mm wide, oblique to almost transverse, round to ovate-elliptic, the surface flat to broadly convex; *perianth* 8–10 mm long, 1.5–2.5 mm maximum width, oblong-sigmoid, narrowed to 1 mm wide at the curve, tomentose outside, glabrous inside, the inner surface scarcely visible, after anthesis, falling as a coherent unit; *tepals* attached to the toral rim; *limb* 2.5 mm long, 2 mm wide, white, ovoid, declined, densely sericeous-tomentose to tomentose-villous, tightly enclosing the style-end; *anthers* 1.2 mm long; *pollen* translucent to white or pink, sometimes abundant. *Fruit* 12–19 mm long, 8 mm wide, on inflexed pedicel, laterally compressed, oblong/ovoid, the apex attenuate; *style* persistent; *pericarp c.* 0.5 mm thick; *exocarp* tomentose, purple-striped or in irregular patches, ridged on dorsal side; *mesocarp* crustaceous; *endocarp* smooth. *Seed* 15 mm long, 5 mm wide, elliptic, rugose. (Figs 1B, 2)

Fig. 2. *Grevillea macleayana*. A. Flowers and foliage from a medium spreading shrub near Point Perpendicular lighthouse. B. A prostrate plant from near Racecourse Creek, Ulladulla, in cultivation. C. Decumbent shrub near Currarong on track to Abrahams Bosom. D. Sub-arborescent shrubs near Blenheim Beach. Photos: A, C, D: P. Olde; B: M. Noake.

Distribution: From the South Coast of New South Wales, between Nowra and the Jervis Bay area, Green Patch, Honeymoon Bay, Point Perpendicular, Currarong, Hyams Beach, Blenheim Beach, Bream Beach, Vincentia, extending patchily west of Nowra to Bundanoon and then south *c.* 65 km to Ulladulla.

Phenology: Flowers from May to February with spasmodic flowers at other times.

Habitat and ecology: Grows generally in relatively small, isolated populations of scattered plants, occasionally in numerically large populations. Usually found in elevated coastal scrub, heath or woodland in well-drained, acid sand derived from sandstone. Associated species include *Banksia serrata, B. ericifolia, B. integrifolia, Hakea sericea* and other common coastal species.

Conservation status: Although not currently considered to be endangered, *G. macleayana* is mostly restricted to an area < 70 km long, 20 km wide, in areas that receive considerable tourist traffic in summer. Although it is

contained in several Nature Reserves and National Parks, some of these areas are close to habitation and have been degraded by over-use.

Etymology: A suggestion of J.H. Maiden in 1892 that Mueller should honour Sir William Macleay (1820–1891), pastoralist, MP and 'promoter of Science in New South Wales', in the epithet was not at the time brought into effect. However, D.J. McGillivray (1986) later acted within the same spirit in choosing the epithet, though using a different specimen on which to base the name.

Variation: McGillivray and Makinson (1993: 56) drew attention to two variants, then known from single specimens, notable for their morphological variation and geographic disjunction from the main areas of occurrence of *G. macleayana*. The plants from Diamond Creek in Deua National Park, the first variant recognised, are here treated as *Grevillea gilmourii,* a separately distinct species. The specimen from the Bundanoon area (NSW 1281169) was treated as a second variant, the '*Woolly form*', by Olde and Marriott (1995b: 9), because of its slightly larger common bracts and the 'rather more profuse and woolly indumentum on the flowers' (McGillivray and Makinson (1993: 56). The '*Woolly form*' continues to be recognised informally here as a geographically disjunct variant (*c.* 40 km north-west of, and inland from, the nearest other occurrence of the typical populations) but warrants further study. Should the morphological variation and geographic disjunction be corroborated by plants in a viable population, then the status of this form will need review. It is currently still known only from a single collection made in 1963 (*Coveny s.n.*, NSW 1281169).

Olde and Marriott (1995b: 9) also recognised a '*Coastal form*' which is more or less co-occurring with the main or typical populations. Among them a plant near Ulladulla (*Olde* 93/01 – NSW 899105; *Orme* 410 *et al.* – NSW 617990) was noted as being prostrate and has been introduced into cultivation where it maintains a ground-hugging, spreading habit. A similar, slightly larger plant *c.* 0.5 m high, 1 m wide, was found on the main walking track at Abraham's Bosom, near Currarong by the author and a study party in 2020.

Ayre (1994) found that an unusually large population comprising hundreds of plants at Honeymoon Bay consisted of atypically tall plants more than 4 m high. These were found as understorey plants within a eucalypt woodland, an uncommon ecotone at variance with populations typically co-dominant in heath or low woodland.

Discussion: Between 1993 and 2009, honours, post-doctoral students and lecturers at the University of Wollongong have focused on *G. macleayana* in a series of ecological, pollination and genetic studies.

Harriss and Whelan (1993) found that *G. macleayana* was self-compatible and that there was virtually no difference in fruit set resulting from autogamy, geitnogamy and xenogamy. Ayre *et al.* (1994) reported that in most populations (3 out of 4) the plants were almost all completely selfed or inbred. In the remaining population, the plants were highly xenogamous. Although the mode of pollination is highly variable, the species appears to well-tolerate high levels of inbreeding. Edwards and Whelan (1995) investigated the soil-stored seed bank and found no seeds outside the existing canopy of living plants. Seeds found were small in number and germinated erratically. 75% of all seed was innately dormant. Vaughton (1995) studied whether *G. macleayana* engaged in selective abortion of less vigorous progeny to enhance the average quality of its seed crop but found that, notwithstanding high levels of fruit abortion in early development, there was no difference between fruits arising from differing modes of pollination. Vaughton (1996) followed up this study with a pollinator comparison in which she found that European honeybees were less efficient pollinators than nectar-feeding birds in *G. macleayana*. Vaughton (1998) next turned to a study of the size and dynamics of the soil seed bank in order to identify fire frequencies that might threaten population survival. Although plants began flowering only 2 years after fire, maximum seed production did not occur for about 15–16 years when plants reached full size, after which senescence set in and seed production declined. More than 95% of flowers failed to develop fruits. Of the initiated fruits, 60% aborted, 27% were attacked by parrots and only 13% matured. Mature seeds were also consumed and dispersed by rodents after falling to ground. Seed recruitment was negligible without fire but after fire, seedlings outnumbered adults 20:1 and there was a 90% survival rate in years with above average rainfall. Vaughton (1998) concluded that population numbers are limited by the size and dynamics of the seed bank if fire intervals are less than 10 years or greater than 25 years.

Hogbin *et al.* (1998) looked at genetic variation and reproductive success of road-verge populations. They found that three road verge populations under study produced significantly more inflorescences and seed than three nearby non-verge populations. They also detected similar levels of genetic variability within and among road-verge and non-verge populations. They concluded that all three road-verge populations had relatively great conservation value, as all were apparently as fecund and as genetically diverse as conspecific non-verge populations. England *et al.* (2001) found that honeybee activity is so high that the contribution of birds to pollination in *G. macleayana* is sometimes relatively trivial. England *et al.* (2002) argued that natural patterns of pollen and seed dispersal, coupled with a patchy, fire-shaped distribution, may have restricted long-distance

gene flow in the past. England *et al.* (2003) studied the effect of anthropogenic disturbance to the seed bank on the genetic structure of populations. They found that at two sites, disturbed by road building, mixing of the seed bank was evident, countering naturally low dispersal and elevated selfing due to honeybees. Pollinator activities may be expected to fluctuate from one flowering season to the next, as well as between populations. Whelan *et al.* (2009) concluded that the characteristics of bird visits to *G. macleayana* are sufficient to produce significant variation in outcrossing rates among sites, especially in the presence of honey-bees, which are likely to be responsible for rapid pollen removal from flowers and little pollen deposition on flowers of distant plants. In addition to these summarised studies, Lloyd (2006) presented an extensive doctoral thesis to the University of Wollongong concerning the pollination ecology and reproductive success of *Grevillea macleayana*.

Selected specimens: New South Wales: Fauna Reserve, just past Ulladulla, *J.Basset s.n.*, 19 Nov 1971 (NSW 544133); Nowra–Nerriga, *J.Boorman s.n.*, Feb 1910 (NSW 544128); Nowra–Turpentine, *J.Boorman s.n.*, 1915 (NSW 92417); Nowra Airfield, *R.F.Brown* 2310 & *P.M.Olde,* 20 Aug 1988 (NSW); cnr Hames and Braidwood Rds, West of Nowra, *R.F.Brown* 2416 & *P.M.Olde*, 20 Aug 1988 (NSW); Ulladulla, *R.H.Cambage 3495*, 28 Dec 1911 (NSW 617990); Jindelara Creek, Milton, *R.H.Cambage s.n.*, 1 Jan 1918 (NSW 92430, SYD); 'Hell Hole' between Tomerong and Nerriga Road, *J.Cole s.n.*, 5 Oct 1943 (NSW 92418); 0.5 mi [0.8 km] NW of lighthouse, Pt Perpendicular, *E.F.Constable s.n.*, 7 Oct 1960 (MO, NSW 52340); Pt Perpendicular Beecroft Peninsula Jervis Bay, *J.Cosh s.n.,* 17 Sep 1984 (WOLL); Bundanoon area, *R.Coveny s.n.,* 5 Oct 1963 (NSW 1281169); Cave Beach Rd., 4.5 km SW of Jervis Bay, *R.Coveny* 3707, 12 Oct 1971 (NSW 544131); Jervis Bay and ?Cruckadille, *C.W.Darley s.n.*, 1895 (NSW 92427); Cave Beach Rd., 1 km N of ANBG Annexe entrance, *F.W.Howe* 54, 12 Sep 1983 (AD, CANB 8317598, LE, MEL 713984, NSW 473989, NY, PRE); Along road to Green Point, 2 km from junction of Green Point Road and Point Perpendicular Road, Beecroft Peninsula, Jervis Bay, *M.Kennedy* 576 & *D.West*, 28 Sep 1993 (NSW 277638); Jervis Bay, *J.H.Maiden s.n.*, 28 Jul 1892 (MEL 98862; NSW 544130); Jervis Bay, *J.H.Maiden s.n.*, Jul 1899 (NSW 92420); Hyams Beach, Jervis Bay NP, *T.Mason s.n.,* 10 Nov 2002 (WOLL 11459); Parma Creek Nature Reserve, beside Braidwood–Nowra Road, SW of Albatross Navy Base, *K.L.McDougall* 955, 5 Sep 2001 (MEL 2210127, NSW); Behind Blenheim Beach, Vincentia, *J.Millott s.n.*, 7 Sep 2002 (WOLL 7593); Abrahams Bosom Reserve, Currarong, *K.Mills s.n.,* 4 Sep 1987 (NSW544132); Ettrema Gorge, Morton National Park, *K.Mills s.n.*, 5 Jun 1987 (WOLL 807); Princes Highway, Racecourse Creek, Ulladulla, *P.M.Olde* 93/01, 22 Jan 1993 (BRI, MEL, NSW 899105); Around the water tower, Vincentia, *P.M.Olde* 97/24, 24 Oct 1997 (BRI, NSW 535288); 50 m along Kings Point Road from Princes Highway, Ulladulla, *A.E.Orme* 410, *P.M.Olde, N.R.Marriott*, 31 Oct 2003 (NSW 617990); at entrance to Jervis Bay Botanic Gardens Annexe, Jervis Bay National Park, *B.Rann* 1, 5 Aug 1993 (NSW 274778); Jervis Bay Beach, near Naval College, *F.A.Rodway s.n.*, Oct 1923 (NSW 92425); 1.5 km W of Commonwealth Naval Base, *J.H.Willis s.n.,* 20 Mar 1954 (MEL 98864); South Pacific Heathland Reserve, Coral Crescent, 1.4 km S of Ulladulla Post Office, *P.H.Weston* 3192, 20 Jun 2008 (CANB 703191, NSW 768982).

2. *Grevillea gilmourii* Olde, *sp. nov.*

Type: New South Wales: Diamond Ck., NW of Coondella Trig., Deua National Park, *P.Gilmour* 4832, 16 Oct 1984 (holo: NSW 473991; iso: CBG 8413639 (2 sheets), ERBG-8783).

Grevillea macleayana '*Deua form*' *sensu* Olde & Marriott (1995b: 9)

Seedlings not seen. *Mature plants* erect, seed-obligate, probably self-compatible, non-lignotuberous *trees* 4–7 m high with spreading crown. *Branchlets* angular in cross-section, rusty-tomentose with subglabrous brown striations. *New growth* dull pink. *Adult leaves* dorsiventral, simple and divided, 7.5–19.2 cm long, 20–75 mm wide, ascending to spreading, not crowded (internodes to 100 mm), petiolate, coriaceous; *simple leaves* 7.5–15 cm long, 20–40 mm maximum width, narrow-elliptic to oblong-elliptic; *divided leaves* 10–19.2 cm long, 55–75 mm maximum width, obovate in outline, bifid or irregularly pinnatifid with 2–3(–6) lobes; *leaf lobes* 5–8 cm long, 16–25 mm wide, broadly to narrowly subtriangular to broadly obovate; *petioles* 5–10 mm long; *leaf base* cuneate, sometimes unequal; *apex of leaves and lobes* acute to obtuse, mucronate, the mucro decurved, non-pungent; *leaf margins* entire or lobed, flat to shortly recurved, sometimes undulate; *venation* mixed, mostly brochidodromous but usually a few lateral veins terminating in an excurrent mucro or spine; *adaxial surface* glabrous or almost so, dull, midvein discolorous, clearly evident, impressed; *lateral veins* and *intramarginal veins* narrower, similar; *lateral veins* widely angled at 60°–70° to the midvein; *edge-veins* sometimes evident, enlarged or not, green, glabrous; *reticulum* fine, very faintly evident; *abaxial surface* densely white-tomentose, or with scattered rusty hairs, a ferruginous indumentum covering the prominently raised, discolorous midvein; secondary veins and anastomosing penninervation faintly evident; *texture* coriaceous. *Conflorescence* 3.5–4 cm long, 20–25 mm wide, terminal or subterminal, leaf-opposed, erect, unbranched, acropetal, broadly secund; *conflorescence buds* narrowly ovoid, exserted bracts evident, pedunculate; *peduncles* 5–15 mm long, rusty-tomentose; *floral rachises* 25–45 mm long, 1.5 mm thick, discolorous, white-tomentose, with an apical flowerless extension *c.* 3 mm long; *common bracts* 1.8–2.5 mm long, 1.5 mm wide, ovate,

shallowly concavo-convex to flat, tomentose-villous outside, glabrous inside, persistent at anthesis. *Flower colour:* perianth greenish white becoming pale pink outside, pink inside; limb white; style pale pink; style-end green becoming yellow. *Flowers* zygomorphic, inodorous, nectariferous, acroscopic; *pedicels* 2 mm long, 1–1.5 mm thick, white, pubescent-tomentose; *torus* 1.5 mm across, slightly oblique; *nectary* semi-annular, rising 0.4 mm above the toral rim, the margin uneven to minutely toothed; *pistils* 22–23 mm long; *gynophore* 1.5 mm long, openly tomentose-villous; *ovary* villous, prominent ventrally; *style* glabrous except for ascending hairs at base above the ovary, straight or undulate, oblique immediately after anthesis, ultimately strongly retrorse; s*tyle-end* abruptly divergent from style, unguiform; *pollen-presenter* 1.25 mm long, 1 mm wide, oblique, elliptic, the surface flat to broadly convex; *perianth* 10 mm long, 1.5 mm maximum width, oblong-sigmoid, not dilated at base, narrowed to 1 mm wide at the curve, openly subsericeous on the abaxial surface, the hairs white or red intermixed, the adaxial surface partly visible at anthesis, glabrous, falling as a coherent unit; *tepals* attached to the toral rim; *limb* 2.5 mm long, 2 mm wide, white, ellipsoid, nodding to declined, densely tomentose-villous, tightly enclosing the style-end; *anthers* 1.2 mm long; *pollen* maroon–dark purple, abundant. *Fruit* and *Seed* not seen. (Fig. 3)

Diagnostic characters: Closely related to *Grevillea macleayana* (McGill.) Olde & Marriott, but differing in its taller, tree-like habit (4–7 m high) with spreading crown versus a spreading shrub [(0.3–)1.5–2.5(–4) m high], and in its leaves both simple and divided versus all simple and entire.

Distribution: Known only from the type location in Deua National Park, New South Wales, which is *c.* 100 km south-west of the nearest known population of *G. macleayana*.

Phenology: Cultivated plants and specimen records indicate flowering from late winter to summer.

Habitat and ecology: Found on a terrace at a bend in the creek. Soils are deep brown clay derived from volcanic rhyolite mixed with Silurian porphyry, formed in this area as part of the Comerang Volcanic Series. It occurs in open forest with upper storey including *Acacia sylvestris*, *Allocasuarina littoralis* in association with a dense understorey of *Hakea macraeana*, *Phebalium squamulosum* subsp. *squamulosum*, *Prostanthera lasianthos* and *P. incisa*. Recorded summer temperatures range from 6.6°–44.8°C. Lowest winter minimum is -5.6°C. Rainfall varies from 480–1160 mm annually. Cultivated plants at Eurobodalla Botanic Garden have regenerated from seed after fire impacted the site.

Conservation status: *Grevillea gilmourii* is known from a single population which is infrequently monitored. Because of its restricted distribution and low population number, it must be treated as critically endangered in the wild. Feral goats, deer, climate change, increased fire frequency, lower precipitation and other stochastic events are all seen here as potential threats to regenerating seedlings and therefore to its ongoing viability. Like many other species that occur in steep habitats with volcanic origins, *G. gilmourii* is known from a single population.

Etymology: This species is named for its discoverer Phillip 'Phil' Gilmour (fl. 1970–), an ecologist whose collections from remote areas of this difficult south-coast terrain are worthy of greater recognition.

Variation: A reasonably uniform species but with considerable variation in the number and shape of leaf lobes. Some plants have most leaves entire with only a few lobed. Others have most leaves divided and only a few entire.

Discussion: McGillivray and Makinson (1993: 56) have noted the closer morphological similarity of *Grevillea gilmourii* to *G. macleayana,* in preference to *G. barklyana,* which differs in its ovary and gynophore with a close sericeous indumentum, its leaves longer and with more numerous lobes, and in its pollen-presenter subconical. From its comparator *G. macleayana*, which is now circumscribed as having only entire leaves, *G. gilmourii* also differs in being geographically disjunct, in its occurrence at higher elevations (130 m) and on volcanic soils, in its riparian habitat in tall wet sclerophyll forest. *Grevillea gilmourii* differs morphologically from *G. macleayana* in its arborescent habit 4–7 m high with a spreading crown and in having some to most of its leaves always divided. Its pollen is noticeably maroon-red coloured whereas that of *G. macleayana* is transparent to pink. *Grevillea macleayana* is also distinguished by its mostly shrubby habit (to *c.* 2 m high, rarely to 4 m in Eucalypt woodland). The differences provide clear evidence of lineage divergence between *G. macleayana* and *G. gilmourii*.

Specimens seen: New South Wales: Deua National Park, Diamond Creek, 600 m upstream from junction with Coondella Creek, *N.Taws* 360, 2 Jan 1994 (CBG 9400110, NSW 943097); Deua National Park, Diamond Creek, 600 m upstream from junction with Coondella Creek, *N.Taws* 361, *A.Scott, W.Marsden*, 2 Jan 1994 (CBG 9400008, NSW 9430098, NSW 383047).

Fig. 3. *Grevillea gilmourii*. A. Young plant in cultivation, Moruya, NSW. B. Conflorescence and new growth in cultivation. Photos: M. Noake.

3. ***Grevillea milleriana*** Olde, *sp. nov*.

Type: New South Wales: Heathcote Soaring League Model airfield, crown lease adjacent to Dharawal Nature Reserve, Old Princes Highway, Maddens Plains, Central Coast, NSW, *P.M.Olde 21/01 & G.P.Phillips*, 22 Sep 2021 (holo: NSW 1115010; iso: CANB *distribuendus*).

Seedlings not seen. *Mature plants* spreading, subprostrate, seed-obligate, probably self-compatible, non-lignotuberous *shrubs*, *c*. 0.3 m high, 0.5 m wide with lower branches trailing on ground. *Branchlets* angular in cross-section, openly brown-tomentose with brown striations. *New growth* not seen. *Adult leaves* dorsiventral, simple and divided, (0.7–)5–8.5 cm long, (0.7–)15–35 mm wide, ascending to spreading, not crowded (internodes to 20 mm), petiolate, leathery; *simple leaves* 5–6 cm long, 20 mm wide, elliptic or oblong-elliptic; *divided leaves* 6–8.5 cm long, 20–30 mm wide, obovate to elliptic, usually with 1–8 lobes; *leaf lobes* 2–6 mm long, 5–10 mm wide at base, broadly triangular; *petioles* 5–6 mm long; *leaf base* broadly cuneate; *leaf apex* obtuse, mucronate, the mucro decurved, non-pungent; *leaf margins* entire or lobed, flat or slightly recurved, slightly undulate; *venation* mixed, mostly brochidodromous but usually a few lateral veins terminating in an excurrent mucro or spine; *adaxial surface* glabrous or nearly so, dull, the midvein discolorous, conspicuous, impressed; *lateral veins* and *intramarginal veins* narrower, similar; *lateral veins* acutely-angled at *c*. 45° to midvein; *edge-veins* obscure; *reticulum* obscure to faintly evident; *abaxial surface* densely white-sericeous, the midvein and lateral veins prominently to slightly raised, the midvein discolorous, subglabrous, green; secondary veins and anastomosing penninervation faintly evident; *texture* coriaceous. *Conflorescences* 35–45 mm long, 15 mm wide, sub-terminal, leaf-opposed, erect, unbranched, acropetal, conico-secund; *conflorescence buds* cylindrical to narrowly ovoid, pedunculate; *peduncles* 5–12 mm long, white-sericeous; *floral rachises* 40–50 mm long, 1.2–1.8 mm thick, concolorous, white-sericeous, with apical, flowerless extension *c*. 3.5 mm long; *common bracts* 2–2.5 mm long, 2 mm wide, ovate, strongly incurved from just above base, sericeous outside, glabrous or with a few scattered hairs inside, caducous at or just before anthesis. *Flower colour*: perianth pink outside, purple-pink inside; limb brown-sericeous; style reddish-pink; pollen-presenter yellow. *Flowers* zygomorphic, inodorous, nectariferous, acroscopic; *pedicels* 3.25–3.5 mm long, 0.5–0.75 mm thick, openly white-sericeous with some hair contents coloured; *torus* 0.8–1.5 mm across, oblique; *nectary* semi-annular, rising 0.2–0.4 mm above the toral rim, the margin uneven to minutely toothed; *pistils* (14–)18–19 mm long; *gynophore* 1–1.25 mm long, white-sericeous with scattered red hairs interspersed; *ovary* white-sericeous with scattered red hairs intermingled, prominent ventrally; *style* glabrous except for appressed hairs at base above the ovary, ascending to erect after anthesis; *style-end* abruptly divergent from style, unguiform; *pollen presenter* 1.2–1.5 mm long, 1.2–1.5 mm wide, slightly oblique, round to broadly elliptic, the surface broadly conical, the stigma c. 0.5 mm above base; *perianth* 6–7 mm long, 1.2–1.8 mm maximum width, narrowly ovoid-sigmoid, 0.6–1.2 mm wide at the curve, sparingly white-sericeous outside, glabrous inside, the adaxial surface partly visible at anthesis, after anthesis falling as a coherent unit; *tepals* attached to the toral rim; *perianth limb* 1.25–1.8 mm long, 1.75–2 mm wide, ovoid to depressed-globose, declined to revolute, densely ferrugineo-sericeous, tightly enclosing the style-end; *anthers* 0.5 mm long; *pollen* yellow. *Fruits* and *Seeds* not seen. (Figs 4, 5)

Diagnostic characters: Differs from *G. macleayana* (McGill) Olde & Marriott in some of its leaves shallowly 1-8-lobed or toothed versus always entire, the abaxial surface sericeous versus curly-tomentose, its pedicels longer (3.25–3.5 mm versus 1.5–2.5 mm), its pistils shorter (14–)18–19 mm long versus 22–28.5 mm long, its perianth limb rusty-sericeous versus white-tomentose, its anthers 0.5 mm long versus 1.2 mm long, its pollen white to yellow versus translucent to white or pale pink, its ovary and gynophore sericeous versus tomentose.

Distribution: New South Wales. Confined to a small area near Darkes Forest, *c*. 60 km S of Sydney.

Phenology: Flowering commences at the end of August and continues probably throughout spring.

Habitat and ecology: Grows in wet, sandy grey loam in densely vegetated upland swamp heath dominated by low-growing clumps of *Hakea teretifolia* and sedges, associated with *Actinotus minor*, *Banksia paludosa, Isopogon anemonifolius, Petrophile pulchella, Bauera microphylla, Allocasuarina paludosa, Lepidosperma forsythii, Epacris obtusifolia, Xanthorrhoea resinosa, Xyris* sp. The nectariferous flowers are ornithophilous, a pollination syndrome discussed by Carolin (1961) and defined here as flowers with the following characteristics: bright coloration, inodorous, tube-shaped with strong tepal structure and coherence, prominently displayed, and borne on branches sufficiently strong, and with stigmas on overarching pistils capable both of depositing pollen on a probing nectarivore and receiving transferred pollen. Honey-eaters (Meliphagidae) are the common suspect pollinators in Australia but none have yet been observed on *G. milleriana.*

Conservation status: Presently known from a single individual plant although other sightings have been reported elsewhere in the Darkes Forest area. The only confirmed 'population' is adjacent to a regularly mown airfield which will provide considerable challenges for conservation management.

Fig. 4. *Grevillea milleriana*. A. Plant in natural habitat. Photo: P. Olde.

Fig. 5. *Grevillea milleriana*. A. Conflorescence. B–D. Leaf variation. Photos: G. Phillips.

Etymology: The epithet recognises the joint discovery of this species in August 2021 by ecologists Robert T. Miller (R.T.Mill.) (1950–) and Janice Miller, née Peters (1953–).

Discussion: This species was first brought under notice by Mr Nathan Kirkwood (Olde 2002) who reported that he had seen various *Grevillea* species of interest in association with *G. longifolia* while mountain-bike riding as a youth in the Darkes Forest area many years earlier. An area, subsequently confirmed as wrong, was searched by a party which included Mr Robert Miller, Richard Johnston (then seed collector, Australian Botanic Garden, Mt Annan) and the author but no plants were located (Olde 2004). Mr Miller subsequently spent much time searching the area in a private capacity without results. However, more recently, he and his wife Jan, chanced upon a single plant, from which we infer a small population that is not extant in the immediate vicinity. Although the species is known currently from only one living plant, it is expected that further populations will be located in the coming years. The plant from which the type specimen was collected has been previously slashed to ground level and has regenerated from branches spreading below the level of the mower blade.

A follow-up visit to the site with Mr Kirkwood resulted in positive recognition of *G. milleriana* that he now admits to having mis-identified as a youth as *G. caleyi* (Olde 2004). He then pointed to a second site, where he remembered seeing plants: a track heading south off Darkes Forest Rd that leads towards a branch of Waratah Rivulet, the same watercourse on which *G. milleriana* occurs. An immediate search could not be conducted because the area has been made inaccessible by Sydney Water environmental exclusion fencing. Mr Kirkwood also advised that he saw the same plant along O'Hare's Creek, also yet to be searched. The anecdotal existence of *G. milleriana* at multiple sites suggests that it is not a hybrid.

Although the possibility that *G. milleriana* represents the successful establishment of a self-sown seedling arising from horticulture or the wild cannot be eliminated, it is nonetheless considered to be highly improbable. Based on floral morphology, at least one of its putative parents would have be drawn from a species in the *G. barklyana* alliance, the nearest wild source being *G. macleayana*, 100 km to the south. If *G. milleriana* is a self-sown hybrid seedling then distance strongly mitigates the likelihood of wild plants of *G. macleayana* as a putative parent. Furthermore, almost 60% of fertile seed of *G. macleayana* examined by Lloyd (2006) was found to selfed, so it is not a wildly promiscuous species.

Grevillea macleayana has been sold in native nurseries during the 1980s but it is not generally long-lived in the Sydney region, is not widely planted, and has never been used successfully as a landscape plant. Furthermore, there is no human habitation or home landscaping in the immediate area of the type locality, although a school is located further to the south and a golf club is opposite.

Grevillea macleayana has figured putatively in two hybrid cultivars, *G.* 'Coastal Glow' = *G.* 'Frampton's Hybrid' = *G. longifolia* × *G. macleayana,* and *G.* 'Brookvale Letitia' (*G. macleayana* × *G. acanthifolia*). The latter cultivar arose in Queensland in horticulture and was never sold in New South Wales. It has not been seen or cultivated in over 40 years. The former is a robust shrub to 3 m in height, requiring good garden conditions, rarely cultivated and not known for its fertility or the production of garden seedlings. Moreover, a planting of neither cultivar was found on the adjacent golf course. *Grevillea longifolia* cannot be entirely ruled out as a possible parent of a putative hybrid with *G. macleayana*. However, the likelihood of a natural connect is ruled out by geography and the low-growing habit of *G. milleriana* is not really a conceivable product of hybridisation between these two robust shrubby species.

The possibility that *G. milleriana* is a hybrid between *G. laurifolia* and *G. macleayana*, neither of which occur nearby in nature, has been entertained but rejected because of the unlikely chance that two entire-leaved species would produce a plant with divided leaves. However, *G. laurifolia* is known to hybridise with *G. acanthifolia* with which it co-occurs in the wild. *Grevillea* × *gaudichaudii* was named from a hybrid swarm still extant in the upper Blue Mountains and there are a couple of hybrids with it as putative parent including *G.* 'Grassfire' and *G.* 'Hunter Beauty'. However, these latter two are either manipulated hybrids or occur in botanical collections with both parents present. Neither of these cultivars have set seed in cultivation and are therefore presumed to be of low fertility.

Grevillea barklyana, or a hybrid thereof, is grown in horticulture. Seedlings emanating from this species are always robust shrubs 2–4 m high and produce wide leaves with multiple, deeply incised, triangular lobes. They tend to arise only when the parent plant dies. *Grevillea* 'Copper Rocket' and *G.* 'Taminga' are the only known daughter cultivars of this species and they are not widely cultivated to my knowledge in the Sydney region, if at all. The likelihood of seed arising from further afield, such as from the Illawarra Grevillea Park, Bulli is also highly doubtful and speculative, as there is no self-sown seedling similar to *G. milleriana* known to have arisen there.

Anecdotal reports of additional wild plants that have been seen and reported since 2002 are given added weight by the discovery of the plant at Maddens Plains. The lack of a reasonable parental source of *G. milleriana* as a

self-sown hybrid, coupled with its own unique morphology unrepresented even closely in hybrid horticulture, and its adaptation to a unique, harsh ecological situation induces me to accept this plant as a biological species worthy of recognition.

Additional specimen seen: New South Wales: Maddens Plains, *P.M.Olde* 21/01, *R.Miller, J.Miller*, 2 Sep 2021 (NSW).

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Dianella lignosa (Asphodelaceae), a new species from the north-west Kimberley region of Western Australia

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Abstract

We here describe *Dianella lignosa* R.L.Barrett & M.D.Barrett (Asphodelaceae) as a new species from the Kimberley region of Western Australia, previously included under *Dianella longifolia* R.Br. The new species is readily identifiable by its thick, woody lateral rhizomes, and also differs from *D. longifolia* in leaf and floral characters.

Keywords: Asphodelaceae; Australia; Systematics; Taxonomy

Introduction

Dianella Lam. is a genus of at least 45 species, and probably many more await formal description (Henderson 1987, 1988, 1991; Carr 2004; Muscat 2017; Muscat *et al.* 2019). The genus is now placed in an expanded definition of Asphodelaceae, having previously been placed within Hemerocallidaceae (Clifford *et al.* 1998) or Phormiaceae (Henderson 1987; Wheeler 1992; Green 1994). The morphology that defines the genus is relatively conserved, and there is a high degree of morphological similarity even with its sister genus *Eccremis* Baker, found in South America (Wurdack & Dorr 2009). Delimitation of species in the genus remains problematic, especially for widespread and morphologically variable taxa (Carr & Horsfall 1995; Carr 2006; Muscat *et al.* 2019).

A few *Dianella* species are considered widespread in the Pacific, as relatively recent dispersers from Australia (Muscat 2017; Muscat *et al.* 2019), largely mirroring dispersal patterns found in *Scaevola* L. (Goodeniaceae; Howarth 2003). The most widespread taxon endemic to Australia is *Dianella longifolia* R.Br. (Brown 1810), which is considered to have a broad distribution in eastern and northern Australia. In its traditional circumscription, the species occurs in south-east South Australia, Victoria, Tasmania, New South Wales, throughout Queensland as far north as the Torres Straight Islands, in the top-end of the Northern Territory and in the West Kimberley of Western Australia (Jessop & Henderson 1986; Henderson 1987; Stanley & Ross 1989; Wheeler 1992; Wilson 1993; Conran 1994; Morris 1994; Western Australian Herbarium 1998 onwards; Melzer & Plumb 2007). It is possible that plants from New Guinea incorrectly assigned to an Indian taxon,

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D. ensifolia (L.) Redouté, could also form part of the *D. longifolia* complex (see Jessop 1979). Henderson (1987) recognised seven varieties in *D. longifolia* as an attempt to define some of the variation within this species.

The lectotype of *D. longifolia* is a specimen collected by Robert Brown near Keppel Bay, Queensland in August 1802, as designated by Henderson (1987: 480). In the strict sense, *D. longifolia* may well be restricted to eastern-central Queensland and appears to represent a form illustrated by Melzer & Plumb (2007). But considerable morphological variation is included within the name (e.g. Wilson 1993; Conran 1994; Morris 1994; Melzer & Plumb 2007; Barrett *et al.* 2018), and detailed field studies will be needed to define both *D. longifolia* and any potential segregates, especially if true *D. longifolia* is indeed restricted to eastern-central Queensland.

In a significant advance in our understanding of the *Dianella longifolia* species complex, Muscat (2017) and Muscat *et al.* (2019) produced the first molecular phylogenetic tree for *Dianella* based on relatively extensive sampling of species, in many cases including multiple individuals per species. Importantly, samples ascribed to *D. longifolia* from Western Australia (1 of 1) and the Northern Territory (2 of 3) were recovered as sister to *Dianella rara* R.Br. from the Glasshouse Mountains, Queensland, and *D.* aff. *nervosa* from Blackdown Tableland, Queensland, rather than the majority of samples ascribed to *D. longifolia*, which were placed in a separate clade with strong support. In the analyses of Muscat (2017) and Muscat *et al.* (2019, clade K, fig. 7), samples of *D. longifolia s. lat.* from the Northern Territory potentially form three independent lineages, and in the absence of fieldwork in that region and more detailed sampling for molecular phylogenetics, we refrain from ascribing samples from the Northern Territory to *D. lignosa* at this time. However, all Northern Territory collections should be critically compared to *D. lignosa* in case there are disjunct populations as one Northern Territory sample (DNA D0194440) was recovered sister to the Kimberley sample in Muscat *et al.* (2019).

Kimberley plants previously referred to *Dianella longifolia* form relatively small tussocks of just a few ramets, with spaced, clonal tussocks joined by a woody rhizome (Fig. 1) although the connecting rhizomes eventually decay. The leaves are seasonally senescent, not evergreen, reflecting the long dry season in the Kimberley. Ongoing studies in the Kimberley region continue to reveal significant numbers of new species (Barrett 2015). *Dianella lignosa* joins a suit of recently named geophytic or perennial, petaloid monocots endemic to Western Australia (Macfarlane & Conran 2015; Macfarlane & Keighery 2015; Macfarlane *et al.* 2020), and particularly from the Kimberley region (Barrett 2018; Barrett & Barrett 2015; Barrett *et al.* 2015, 2021, 2022). *Dianella lignosa* is the only *Dianella* species known to occur in the Kimberley region.

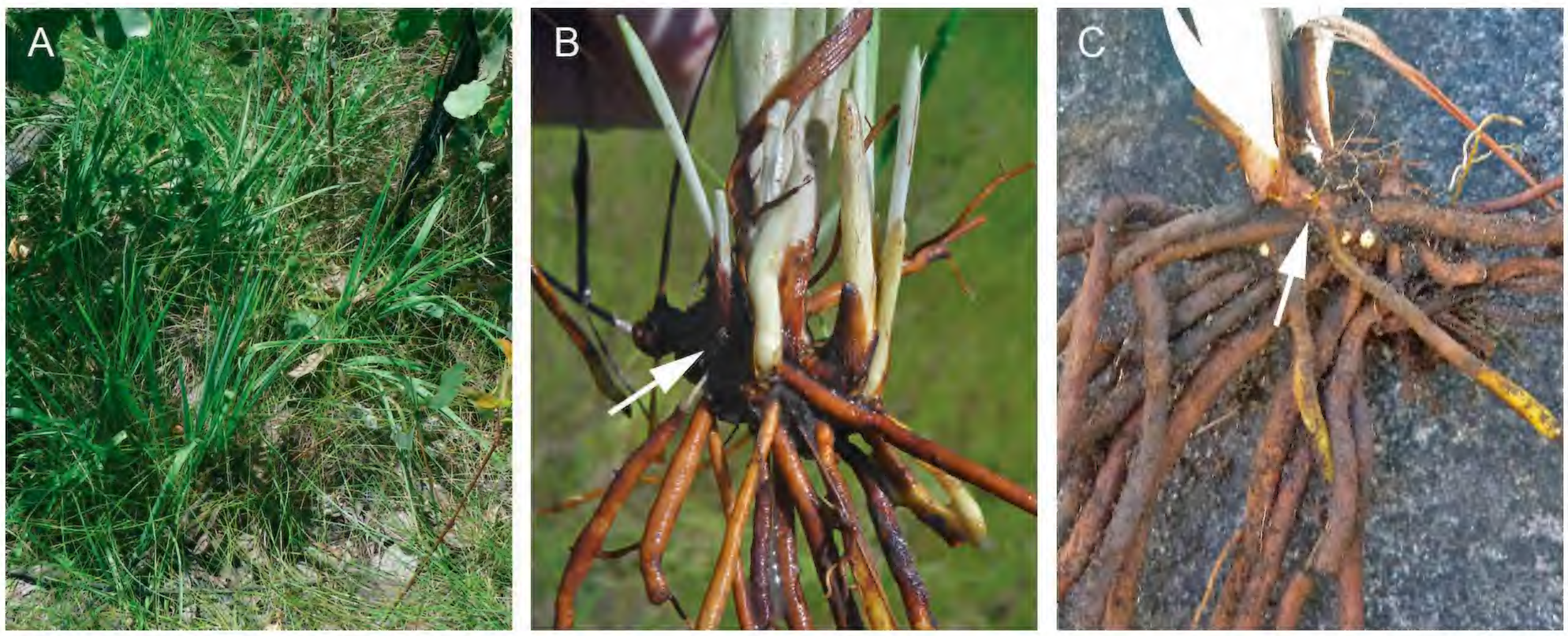

Fig. 1. *Dianella lignosa*. A. Habit. B, C. Plant bases with thickened, fibrous roots and arrows indicating thickened, woody rhizome (broken off near base of ramet). Vouchers: A, B: Edkins Range, 8 km N of Charnley River road crossing (not vouchered). C: *M.D.Barrett & K.W.Dixon MDB 4651* (PERTH). Photographs by M.D.Barrett.

Methods

The description is based on field studies and specimens held at CANB, NSW and PERTH. Selected material held at MEL has also been examined. The format of the description follows Carr & Horsfall (1995).

Taxonomy

Dianella lignosa R.L.Barrett & M.D.Barrett, *sp. nov.*

Type: Western Australia: 9.9 km NE of Mount Agnes, headwaters of Prince Regent River, Mount Elizabeth Station, 28 Jan. 2007, *R.L.Barrett & M.D.Barrett RLB 4054* (holo: PERTH 8042675; iso: DNA D0194440).

Illustration: Wheeler (1992: fig. 298d), as *D. longifolia* var. *longifolia*.

Loosely rhizomatous, caespitose perennial herb to 80(–100) cm high and *c*. 50 cm diameter at the base, ramets adjacent or up to at least 10 cm apart; arising from a thick woody horizontal rhizome up to 30 cm long, 3–6 mm diam, brown, with many thickened, fibrous, brown lateral roots, no evidence of tubers at time of excavation and apparently absent; stems of shoots 12–25 mm long, 4–7 mm diam. Leaves lorate, seasonally senescent, gradually tapering to the apex, 13–46 cm long, (4–)6–12 mm wide, conduplicate, deeply V-shaped in section, relatively soft (not leathery) pale to mid green or dull blue-green, aging grey-green, lightly discolorous, lamina smooth, dull, very finely scabrous along margins and abaxial midrib with a few distant, larger tubercules, keel sharp, but not thickened or winged, margins plane. Leaf sheaths equitant, loosely fan-shaped to tufted, loosely clasping, open (not at all fused), sheath 25–30 mm long, pale at the base. Inflorescence a compound, cymose panicle, ± erect, 40–78 cm long, scape slender, erect to somewhat arching; panicle 8–12 cm long, ± narrow-conical in outline, branches 1–5, spreading, relatively short; raceme-like cymules (2–)5–18 flowered, floral bracts small, ± narrowly triangular acuminate, pale green, 1.5–2.5 mm long, pedicels straight or slightly curved at anthesis, becoming recurved in fruit, (6–)8–21 mm long, regularly spaced. Flowers nodding to somewhat erect, medium sized, weakly but sweetly fragrant, opening early morning, lasting all day; perianth segments all similar, pale blue with a darker purple tint on veins; ± concolorous, adaxially slightly paler; segments erect to strongly recurved; narrow ovate-lanceolate to narrowly elliptic, subacute, 6–10 mm long, 1.8–2.2 mm wide, usually 5-veined. Stamens 4–7 mm long; filaments *c*. 2 mm long, weakly curved, cream ± translucent; strumae subconical, ± terete to slightly compressed in section, glabrous, bright yellow; anthers very pale yellow or cream, uniform in colour throughout; 3–4 mm long, *c*. 1 mm wide, very narrowly cuneate-lanceolate or subconical. Style very pale blue-purple, longer than the anthers, 3.5–6 mm long; ovary pale green, 3-locular, ± subglobular, *c*. 1 mm long, c. 1.3 mm wide. Fruit subglobose to obovoid, ± lumpy, mid-green becoming whitish with a pale blue to purple tint at maturity, somewhat glossy, 3.5–5 mm long, 2.5–4 mm wide. Seeds not seen. (Figs 1, 2)

Diagnostic characters: Differs from *D. longifolia s. str*. in having a thickened woody lateral rhizome (see arrows in fig. 1); the leaves lacking a thickened or winged keel and having plain margins; perianth segments all similar, erect to strongly recurved; fruit pale green to whitish with pale blue to purple tint at maturity.

Other specimens examined: WESTERN AUSTRALIA: 6.2 km ENE of Junction of Pitta Ck and Prince Regent River, 20 Mar. 2015, *M.D.Barrett & K.W.Dixon MDB 4651* (PERTH); Grevillea Gorge, Synnot Range, 32 km NW of Beverley Springs Station Homestead, 14 Jan. 1996, *R.L.Barrett & M.D.Barrett RLB 706* (PERTH); gully on top of sandstone plateau, 8.5 km ENE of Mount Agnes, near headwaters on N side of Prince Regent River, 6 Jan. 2001, *R.L.Barrett & M.O'Connor RLB 1597* (CANB, PERTH); ISM2, step pavements of rough sandstone at top of large mesa, 3 km NNE of Prince Regent River from E boundary of Prince Regent Nature Reserve (1 km E of reserve), 22 Apr. 2008, *R.L.Barrett & M.D.Barrett RLB 4532* (PERTH); south Bachsten Creek, NW of falls on N side of creek in small gully, Prince Regent Nature Reserve [National Park], 21 Jan. 2010, *R.L.Barrett & V.Kessner RLB 6313* (PERTH); S of Bachsten Creek Camp, in Edkins Range, 25 Jan. 2010, *M.Maier & P.Kendrick per R.L.Barrett RLB 6511* (PERTH); DMR 002 site, 1 km S of King Edward River on old Mitchell River Road, 34.3 km NW of Doongan Homestead, 17 May 2011, *R.L.Barrett RLB 7187* (PERTH); 55 km by road WSW of Karungi [Karunjie] Station Homestead turnoff Chapman River - Gibb River - El Questro road, c. 170 km SW of Wyndham, 25 May 1976, *A.C.Beauglehole ACB 51578* (PERTH); 5 km E of Gibb River, Kalumburu Mission road, Aboriginal Paintings area, between Donkey Creek and Gibb River, 190 km WSW of Wyndham, 6 June 1976, *A.C.Beauglehole ACB 52273* (PERTH); Isdell River near Mount Barnett Homestead, June 1905, *W.V.Fitzgerald 1051* (PERTH); Gibb River Homestead, 29 Jan. 1951, *C.A.Gardner 9884, 9955* (PERTH).

Distribution: Considered to be endemic to the north-west Kimberley region of Western Australia, from Charnley River (Beverley Springs) north to Theda and Doongan and east to Gibb River Stations.

Habitat: Usually found growing in sandy soils derived from sandstone, on sand flats or among broken sandstone on ridges, in woodland dominated by *Eucalyptus miniata* and *E. tetrodonta* or sometimes *Corymbia latifolia*. Grows in association with *Buchanania oblongifolia*, *Cajanus marmoratus*, *Commelina ensifolia*, *Decaschistia occidentalis*, *Eriachne* spp., *Erythrophleum* sp., *Galactia tenuiflora*, *Haemodorum ensifolium*, *H. flaviflorum*, *H. griseofuscum*, *H. interrex*, *Murdannia graminea*, *Pandanus spiralis*, *Petalostigma pubescens*, *Polycarpaea longifolia*, *Sarga* spp., *Triodia* spp. and *Triumfetta* spp. Once recorded from the margin of a rainforest patch growing on basalt immediately below sandstone, growing with *Eulophia picta*.

Fig. 2. *Dianella lignosa*. A. Habitat. B. Habit. C. Leaves. D. Inflorescence. E, F. Flowers. G. Infructescence. H, I. Fruit. Vouchers: A: *R.L.Barrett RLB 7187*; B: *R.L.Barrett & M.O'Connor RLB 1597*; C: *R.L.Barrett & V.Kessner RLB 6313*; D, I: *R.L.Barrett & M.D.Barrett RLB 4054*; E, H: *M.D.Barrett & K.W.Dixon MDB 4651* (all PERTH); G: Edkins Range, 8 km N of Charnley River road crossing (not vouchered). Photographs A–E, I by R.L.Barrett; F–H by M.D.Barrett.

Phenology: Flowers are recorded during January, probably continuing to April. Fruit recorded from January–April.

Conservation status: Not well collected due to its wet-season flowering period and seasonally senescent leaves, but probably relatively frequent within its area of distribution and not considered threatened. Occurs in the Prince Regent National Park.

Common name: Kimberley Flax Lily.

Etymology: From the Latin *lignosus* (wood-like) in reference to the distinctive woody lateral rhizome.

Affinities: This species resembles *Dianella longifolia* R.Br. var. *longifolia* and has previously been included under that species name (Henderson 1987; Wheeler 1992). *Dianella lignosa* differs in the thickened woody lateral rhizome (compact in *D. longifolia*); narrower leaves that lack a pronounced keel and have plane margins (keeled and with usually recurved margins in *D. longifolia*); flowers with all perianth parts similar and erect to strongly recurved; and pale fruit.

Kimberley material also has affinity to specimens from New Guinea generally referred to *D. ensifolia*, but that name is incorrectly applied to those specimens, and *D. ensifolia* correctly applies to an Indian taxon with much broader, glossy leaves. The name *D. ensifolia* has also been misapplied in Australia, including to Kimberley specimens by Fitzgerald (1918). Material from New Guinea examined at CANB and NSW does not appear to have the woody rhizome present in Kimberley and Northern Territory populations historically included under *D. longifolia*.

Notes: Specimens from the Northern Territory are more robust, with larger leaves, inflorescences and flowers. They probably represent a discrete species, but they are mentioned here as they are clearly closer to *D. lignosa* than they are to *D. longifolia* as the Northern Territory and Kimberley plants all have thickened, woody lateral rhizomes. The description above is based only on specimens from the Kimberley region.

Flowers have been observed (at *c.* 4 pm) being buzz-pollinated by a native bee similar in appearance to a honeybee (notes on *M.D.Barrett & K.W.Dixon MDB 4651*).

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A revision of Orchidaceae from the Kimberley region of Western Australia with new species of tropical *Calochilus* and *Dipodium*

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Abstract

Orchidaceae occurring in the Kimberley region of Western Australia are revised. *Calochilus barbarossa* R.L.Barrett, M.D.Barrett & K.W.Dixon, *Calochilus kimberleyensis* R.L.Barrett, M.D.Barrett & M.A.Clem., *Dipodium ammolithum* M.D.Barrett, R.L.Barrett & K.W.Dixon and *Dipodium basalticum* M.D.Barrett, R.L.Barrett & K.W.Dixon are described and illustrated as new species from the Kimberley, one also occurring in the Northern Territory. The genera *Empusa* Lindl., *Habenaria* Willd. *s. str*., *Phoringopsis* D.L.Jones & M.A.Clem., *Spiranthes* Rich. and *Zeuxine* L. have been added to the Western Australian flora since publication of the *Flora of the Kimberley Region*. The taxonomic status of a number of tropical Australian Orchidaceae is discussed with recommendations for future research. Descriptions and illustrations are provided for twenty orchid species recorded in the Kimberley Region (one without a verified voucher). Keys are presented to all Kimberley orchid species.

Introduction

Orchidaceae is one of the largest families of flowering plants, and naturally represents a significant challenge for classification (Dressler 1993, 2005; Chase *et al*. 2003, 2015; Pridgeon *et al*. 1999, 2001, 2003, 2005, 2009, 2014). Nomenclatural complexity is also a significant hinderance to conservation and trade in orchids (Hinsley *et al*. 2018). Australian Orchidaceae have been reviewed by Jones (1988, 2006, 2021). Clements (1989) provided the first detailed nomenclatural checklist for Australian orchids, providing many important typifications and

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clarifying the applications of many doubtful names following the study of type material in European herbaria. Western Australian orchids have been reviewed by Brown *et al.* (2008) and Brown *et al.* (2013). In this context one might expect the taxonomy of Kimberley orchids to be relatively straightforward, however, many questions remain unresolved.

Early notes on Kimberley orchids have been provided by Pate & Dixon (1982), Dixon *et al.* (1989) and Dixon (1994). A history of discovery is documented for species newly recorded from the remote Kimberley region of Western Australia between 1979 and 2016 following a series of targeted wet season field trips. Since the publication of *Flora of the Kimberley Region* (Wilson 1992), fieldwork in the Kimberley region has resulted in the discovery of one new species record for Western Australia from each of the following genera: *Calochilus* R.Br., *Dipodium* R.Br., *Empusa* Lindl., *Habenaria* Willd., *Pecteilis* Raf., *Phoringopsis* D.L.Jones & M.A.Clem. and *Spiranthes* Rich. *Zeuxine oblonga* R.S.Rogers & C.T.White has been collected from near Kununurra by other botanists in the same time period. The four new species described here were previously included as informal taxa in a field guide to the orchids of Western Australia (Brown *et al.* 2013). Twenty species from thirteen genera are now recorded from the Kimberley region. Most of these species occur in the north-west Kimberley, in the highest rainfall zones (Figure 1), and those that also occur in the Northern Territory exhibit large disjunctions.

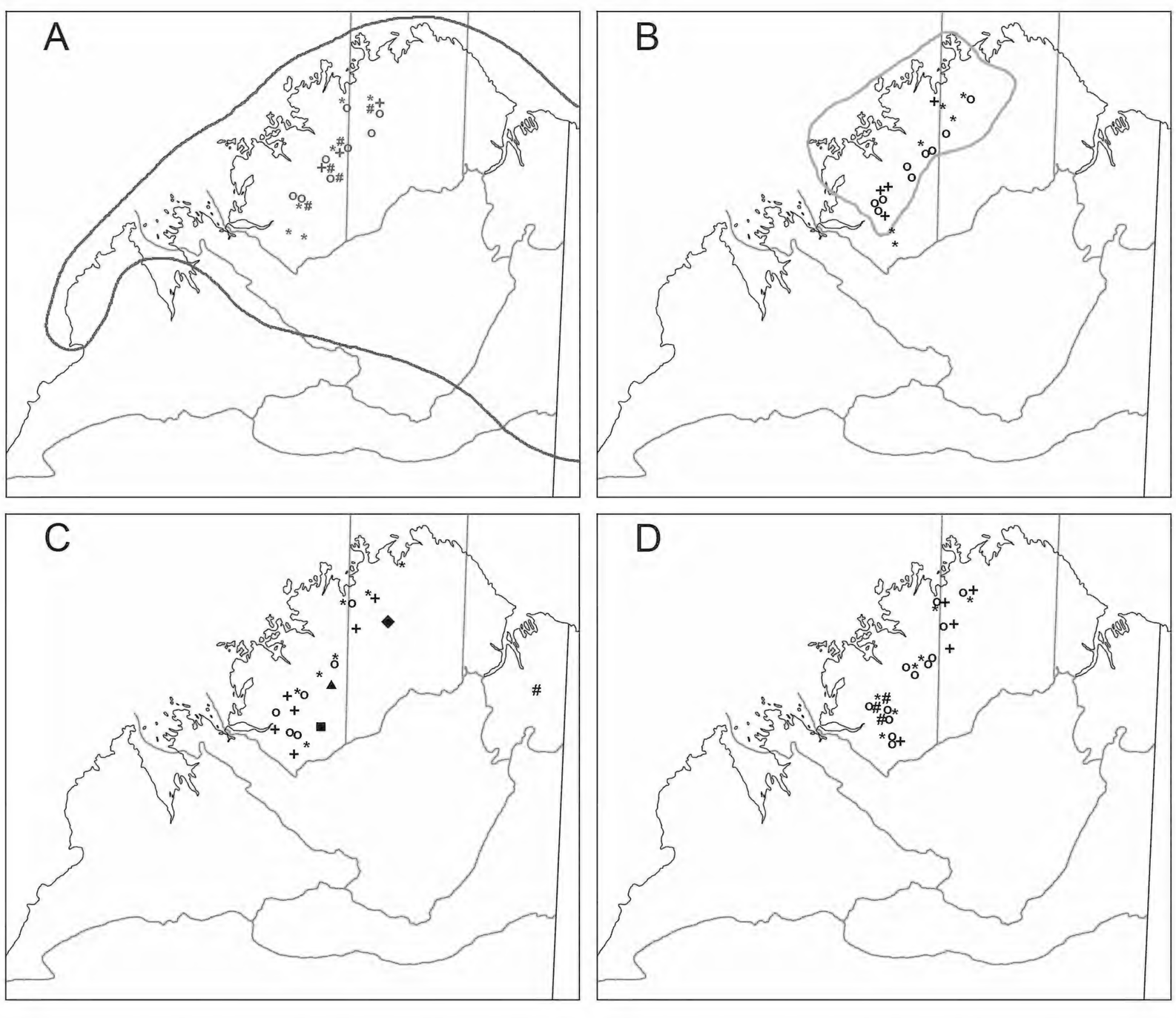

Fig. 1. Distribution of Orchidaceae in the Kimberley Region of Western Australia with the phytogeographic regions of Beard (1990). Map A: *Calochilus barbarossa* (#); *Calochilus kimberleyensis* (o); *Calochilus holtzei* (*); *Cymbidium canaliculatum* (solid line); *Phoringopsis byrnesii* (+). Map B: *Dendrobium dicuphum* (solid line); *Didymoplexis pallens* (+); *Dipodium ammolithum* (o); *Dipodium basalticum* (*). Map C: *Dendrobium foelschei* (♦); *Eulophia bicallosa* (+); *Eulophia picta* (o); *Habenaria hymenophylla* (▲); *Nervilia holochila* (*); *Spiranthes sinensis* (■); *Zeuxine oblonga* (#). Map D: *Empusa habenarina* (#); *Pecteilis elongata* (*); *Pecteilis eurystoma* (o); *Pecteilis ochroleuca* (+).

Three of the species newly described here are considered endemic to the Kimberley region of Western Australia, while *Calochilus barbarossa* R.L.Barrett, M.D.Barrett & K.W.Dixon also occurs around Darwin and on the Tiwi Islands in the Northern Territory. Notes are made on all orchid species recorded for the Kimberley region and keys are presented for these species.

The tropical Kimberley Region of Western Australia covers an area of 300,000 km^2 with habitats ranging from dry monsoon rainforest to arid tropical deserts. The Kimberley has the lowest orchid diversity in Australia after the arid interior. Despite this, it is home to a somewhat remarkable pattern of orchid genera with complex

biogeographic links. Being in relatively close proximity to Indonesia, East Timor and New Guinea, it is not surprising that a number of plant species are shared with that region (Joyce *et al.* 2020; 2021), and some of these shared species are widespread in East and Central Asia. The application of names to many of these widespread orchid species remains problematic as wide-ranging revisions are often required to test species limits. There is also strong representation from Australasian orchid genera such as *Calochilus*, *Dipodium*, *Pecteilis* and *Phoringopsis*, and while much of the orchid flora of this region is considered to be of relatively recent origin, the presence of three endemic orchid species implies a longer evolutionary history for at least some orchid lineages in the region. Aside from the three endemic species, all are found in the Top End of the Northern Territory (NT), except *Spiranthes sinensis* which is absent from the NT but occurs in Cape York.

These biogeographic connections are reflected in the broader flora of the Kimberley region, with a complex mix of biogeographic links. Recent studies have shown that plant populations in the Kimberley often originate from independent dispersal events from Asia relative to populations of the same species in the Northern Territory or Queensland (e.g. Joyce *et al.* 2021).

Methods

Descriptions are based on a combination of fresh and dried material. All relevant orchid specimens at BGPA, CANB, DNA, MEL, NSW and PERTH, along with selected orchid specimens at B, BM, K, and L were examined by at least one the authors. Many species have also been cultivated to flowering in a garden on Beverley Springs (now Charnley River) Station, or in glasshouses at Kings Park & Botanic Garden in Perth, or the Australian National herbarium in Canberra. Orchids were particularly targeted during ecological and taxonomic surveys of the remote north-west Kimberley region of Western Australia over a period of 24 years, at over 100 locations, by the first two authors, in conjunction with Kingsley Dixon, Pat Dundas and Robyn Maher. This included deliberate timing of field work to coincide with maximum flowering times, and specific habitat targeting of both known orchid taxa, and also potential habitats of orchid taxa whose presence was not recorded, but considered possible. This technique identified six additional species for the region over the study period (with a seventh species located by Andrew Mitchell), and location of many previously unknown populations of known orchid species. All orchid species except *Dendrobium foelschei* and *Zeuxine oblonga* have been examined in the field in Western Australia by at least one of the first two authors.

Direct DNA sequencing of endophytes were performed on a single sample of *Dipodium*. Tubers and swollen roots were first washed to remove external dirt, then external surfaces were twice sectioned away with sterile razor blades, to expose a sterile core. DNA was extracted and the Internal Transcribed Spacer (ITS) region amplified using the primers ITS1F and ITS4B, as described in Bougher & Barrett (2020).

Conservation and Ecology

Details of habitats and associated flora of all 20 orchid species recorded from the Kimberley Region are published here for the first time and the specific ecological preferences and related conservation threats are outlined. The region is largely unmanaged wilderness or free-range grazing land, subject to weed invasion, feral animals and high-frequency, broad-scale fires, each of which presents threats to orchid habitats and species. Successful conservation of orchids in the Kimberley region will ultimately rest on habitat conservation as most species are habitat specific. In some cases, specific habitats could be beneficially fenced to protect orchids from damage by feral animals, particularly close to stock watering points. Some habitats may require dedicated weed control to sustain orchid populations.

A third of the 19 extant Kimberley species (no living populations of *Dendrobium foelschei* are known) are considered to be directly threatened in the region and potential threats to the ecological integrity of the region are discussed. Field observations on ecological characteristics were collated between 1992 and 2016 (Table 1; see Barrett 2015 for more background). Many of the 20 orchid species recorded from the Kimberley have only been recorded for this region within this period. Seven species in the region are considered to be of conservation concern (Table 2). This compares to 10 of *c.* 38 orchid species in the neighbouring Northern Territory that are conservation listed (Liddle *et al.* 1994).

Table 1. Number of sites and corresponding habitats for collection of ecological data in the Kimberley Region.

Species	No. of vouchered sites	No. of habitats	Endemic
Calochilus kimberleyensis	10	2	Yes
Calochilus holtzei	12	1	No
Calochilus barbarossa	12	2	No
Cymbidium canaliculatum	10 (90)*	1	No
Dendrobium dicuphum	8 (10)*	1	No
Dendrobium foelschei	(1)*	1	No
Didymoplexis pallens	4	3	No
Dipodium basalticum	6	1	Yes
Dipodium ammolithum	18 (2)*	2	Yes
Empusa habenarina	4	1	No
Eulophia bicallosa	5 (2)*	1	No
Eulophia picta	14 (4)*	1	No
Habenaria hymenophylla	1	1	No
Nervilia holochila	7 (3)*	2	No
Pecteilis elongata	9	1	No
Pecteilis eurystoma	13 (6)*	1	No
Pecteilis ochroleuca	9	1	No
Phoringopsis byrnesii	10	1	No
Spiranthes sinensis	1	1	No
Zeuxine oblonga	1	1	No

* Numbers in parentheses are observations without voucher specimens.

Table 2. Orchid species of conservation concern in the Kimberley region of Western Australia according to FloraBase (Western Australian Herbarium 1998-).

Species	Region*	Conservation Priority	Threats
Didymoplexis pallens	NW	1	Fire, feral ungulates, weeds, small population size
Dipodium basalticum	NW	3	Fire, weeds, small population size
Empusa habenarina	NW	2	Fire, feral ungulates, weeds, small population size
Eulophia bicallosa	NW	3	Fire, feral ungulates
Habenaria hymenophylla	NW	2	Small population size
Spiranthes sinensis	NW	1	Fire, feral ungulates, small population size, altered hydrology
Zeuxine oblonga	NE	2	Fire, weeds, small population size, altered hydrology

*NW corresponds to the North Kimberley and NE corresponds to the Victoria Bonaparte IBRA Bioregions.

Biology

Most orchids found in the Kimberley region are geophytes. Significant geophyte monocot endemism has recently been recognised in the Kimberley with 122 geophytic species now known (out of 701 monocots), with 44 considered endemic to the region (Wheeler 1992; Barrett & Barrett 2015, 2022; Barrett *et al.* 2015; Barrett 2018; M.Barrett & R.Barrett unpubl. data; Table 3). The number of geophytes as a percentage of the total monocot flora is 17%, higher than in southern Australia (7–12%, see Parsons & Hopper 2003) and endemism among Kimberley species of monocot geophytes is just over 36% (Table 3). Geophytes have evolved in response to a number of different environmental factors, including strong seasonality of climate, fire response and aridity of environment (Howard *et al.* 2019). Note that the definition of geophyte adopted by Howard *et al.* (2019) is somewhat broader than many definitions, and most of the grasses listed have thickened rather than fleshy roots.

Table 3. Monocot genera with native geophytic species in the Kimberley, following the definition of geophyte in (Howard *et al.* 2019).

Family	Genus	No. Kimberley species	No. Endemic to Kimberley
Alismataceae	*Caldesia*	1	0
Amaryllidaceae	*Crinum*	3	1
	Proiphys	1	1
Aponogetonaceae	*Aponogeton*	3	3
Araceae	*Amorphophallus*	1	0
	Colocasia	1	0
	Typhonium	8	7
Asparagaceae	*Asparagus*	1	0
	Chlorophytum	1	0
	Lomandra	2	1
	Sowerbaea	1	0
	Thysanotus	2	0
Asphodelaceae	*Caesia*	2	0
	Corynotheca	2	0
	Dianella	1	1
	Tricoryne	1	1
Burmanniaceae	*Burmannia*	1	0
Colchicaceae	*Iphigenia*	1	0
Commelinaceae	*Cartonema*	10	8
	Murdannia	7	4
Cyperaceae	*Cyperus*	5	0
	Eleocharis	3	0
	Scleria	2	0
Dioscoreaceae	*Dioscorea*	2	0
Flagellariaceae	*Flagellaria*	1	0
Haemodoraceae	*Haemodorum*	15	11
Hydrocharitaceae	*Enhalus*	1	0
Hypoxidaceae	*Curculigo*	1	0
	Hypoxis	2	1
Juncaginaceae	*Cycnogeton*	1	0
Orchidaceae	*Calochilus*	3	1
	Didymoplexis	1	0
	Dipodium	2	2
	Empusa	1	0
	Eulophia	2	0
	Habenaria	1	0
	Nervilia	1	0
	Pecteilis	3	0
	Phoringopsis	1	0
	Spiranthes	1	0
	Zeuxine	1	0
Philydraceae	*Philydrum*	1	0
Poaceae	*Eriachne s.l.*	3	2
	Imperata	1	0
	Leersia	1	0
	Neurachne	1	0
	Oryza	2	0
	Pseudochaetochloa	1	0
	Sporobolus	1	0
	Whiteochloa	1	0
Potamogetonaceae	*Potamogeton*	3	0
	Stuckenia	1	0
Smilacaceae	*Smilax*	1	0
Stemonaceae	*Stemona*	1	0
Taccaceae	*Tacca*	2	0
Typhaceae	*Typha*	2	0
Total		**122**	**44**

Of the 17 geophytic species found in the Kimberley Region, 10 species in the genera *Calochilus*, *Habenaria*, *Pecteilis*, *Phoringopsis* and *Spiranthes* all have root tubers which are replaced on an annual basis (Pate & Dixon 1982; Dixon 1991). *Eulophia* species (including former *Geodorum*) produce a series of pseudobulbs, with vegetative material and clonal development arising from the most recent pseudobulb. *Didymoplexis* and most *Dipodium* species are saprophytes with intermittently swollen rhizome segments in *Didymoplexis* or fleshy tuberous roots arising from an abbreviated rhizome in *Dipodium*. *Nervilia* species are highly clonal, with new root tubers ('daughter tuberoids' in Jones 2021) being produced on adventive stems 5–20 cm from the parent plant forming colonies up to three metres in diameter. *Empusa habenarina* is also clonal, with daughter plants being produced adjacent to the parent plant. Jones (2021) suggests that *Pecteilis ochroleuca* and some species of *Calochilus* are semi-obligate saprophytes, with leaves being so reduced as to limit sustenance for plant growth. *Cymbidium canaliculatum* and *Dendrobium dicuphum* are both epiphytic species which produce annual growth of new pseudobulbs. In rare cases, particularly in low light, *Cymbidium canaliculatum* is known to produce elongated rhizomes resulting in new plants.

Dipodium species have limited evidence of chlorophyll and may rely on holomycotrophic systems for growth (Dearnaley & Le Brocque 2006). Jones (2021) records the eastern Australian hyacinth orchid *Dipodium punctatum* as an epiparasite, reliant on fungi that are ectomycorrhizal on root systems of adjacent Myrtaceae species, particularly eucalypts. *Zeuxine oblonga* has a 'fleshy stem' which remains dormant in leaf litter during the dry season, though flowering occurs after the leaves have withered following the end of the wet season (Jones 2021).

Future surveys need to account for the potential presence of geophytic species which are often only observable when flowering. This applies equally to a number of other geophytic taxa in the region (e.g. *Crinum*, *Hypoxis*, *Murdannia*, *Typhonium*).

Pollination

Pollination syndromes are diverse and range from nectar rewards to sexual deception and food mimicry (Stowe 1988). The pollination type also influences flower-life with sexually deceptive flowers remaining open for extended periods (or as in the case of *Phoringopsis*, plants producing blooms over a number of weeks) presumably due to the higher risk associated with non-food pollination systems. *Dendrobium dicuphum* is remarkable in having a bet-hedging system of pollination. This species flowers at the end of the 'wet' season. At least in cultivated plants, early flowers will not self-pollinate, but if open pollination does not occur, the last few flowers that open are autogamously pollinated with these blooms opening for only a few days, ensuring at least some seed set.

Very little literature exists on the pollination of tropical Australian orchids, the available literature summarised by Jones (2021). Pseudocopulation occurs with three species of *Calochilus* and with *Phoringopsis* which is pollinated by thynnid wasps attracted by pheromone production (Mant *et al.* 2002; Jones 2021). *Calochilus barbarossa* is pollinated by scoliid wasps, but may also self-pollinate (R.L. Barrett & M.D. Barrett, pers. obs.). Scoliid wasps are also pollinators of *Dipodium* species (R. Maher, pers. comm.). *Eulophia picta* and *Cymbidium canaliculatum* are apparently pollinated by small native bees (Jones 2021). Australian *Empusa* species are reportedly pollinated by small flies and mosquitos (Jones 2021). Jones (2021) also suggests that the *Habenaria* and *Pecteilis* species in the Kimberley are pollinated by hawkmoths (Sphyngidae). *Spiranthes* species are pollinated by bees in the Apidae and Megachilidae (Bernhardt *et al.* 2017; Kuiter 2018). Pollinators are still unknown for *Didymoplexis* and *Zeuxine*. The authors have observed pollination of two *Calochilus* spp. by scoliid wasps, however actual pollinators in Kimberley region remain unknown for other species. Multiple attempts to locate the pollinators of *Phoringopsis byrnesii* using open flowers as baits were unsuccessful, suggesting its pollinators are rare in the north-west Kimberley, consistent with the observation of very low seed set in this species.

Phenology and seed production

Geophytes have two key drought (or regular dry season) survival processes, either seeds or as bulbs, corms or tubers (sexual and vegetative reproduction). As a strategy for living in the strongly seasonal climate of the Kimberley region, geophytes can be classified as following one of two reproductive strategies. (1) Flower and fruit precociously, dropping seed early in the 'wet' season (Dec/Jan.–Mar/Apr.) so that seedlings can establish and grow during the same 'wet' season, or (2) dropping seed at or after the end of the 'wet' season with seed germinating at the start of the next 'wet' season. Most terrestrial orchids in the Kimberley follow the first pattern, but fertile collections have only been made at the end of the wet season for *Zeuxine* and *Spiranthes* from the Kimberley.

The nature of geophytes with the storage organs described above means that they are not always dependant on rainfall for flowering. In the Kimberley region, *Eulophia bicallosa* and *Nervilia holochila* utilise reserves in

their storage organs to flower precociously (before or at the onset of the 'wet' season) and release seeds with the early rains. This enables establishment of seedlings during the wet season, rather than seeds having to survive the protracted dry season (about 9 months). Most species in the region flower early in the 'wet' season, usually finishing by early February, possibly also avoiding competition with tall grass which reduces visibility for pollinators. *Calochilus holtzei*, a relatively tall species, flowers for an extended period subject to moisture availability. *Eulophia picta* holds its seeds for six months or more, combined with elongation and straightening of the peduncle following fertilization. Fertilization of the flowers also triggers a remarkable elongation of the pedicel in *Didymoplexis pallens* as reported by Hemsley (1884), resulting in up to a trebling in plant height, corresponding somewhat to the height of surrounding grasses as they develop.

Ecology and ecosystem threats

Fire is a pervading force in tropical northern Australia where land is either unmanaged, or managed on a very broad scale (e.g. typical grazing property size in Kimberley is 750,000 acres). Fires are broad and patchy in distribution 'as uncontrolled wildfire' (Russell-Smith *et al.* 2003) or as controlled burns. Approximately one third of the Kimberley region is burnt annually by deliberate 'controlled' burns or wildfire (Fisher *et al.* 2003). One fire in 1994 originated from a tourist's campfire which was not properly extinguished and subsequently burnt for three months and covered almost 100,000 km^2 due to the inaccessibility of the terrain and few local fire-fighters (Peter Saint, pers. comm., R. Barrett pers. obs.). Edwards *et al.* (2003) have observed significant changes in abundance of ground-layer species in a trial savanna woodland site in the Northern Territory subject to frequent fires over a five year period with significant patterns based on life-form, including geophytes such as *Cartonema spicatum* R.Br. Fisher *et al.* (2003), examining patterns of landscape fire and vegetation response in the region, called for 'a thorough appraisal of the status of regional biota in this remote, ostensibly ecologically intact region' and we provide notes on the effects of such fires on orchids in the Kimberley region.

Specific threats to vine thickets and rainforest ecosystems, as key habitats for several Kimberley orchid species, have been documented in recent years with fire and grazing leading to significant increased losses in area over the last 40 years (Kenneally *et al.* 1991, Mangglamarra *et al.* 1991, McKenzie *et al.* 1991, McKenzie & Belbin 1991, Barrett *et al.* 2001).

Grass species richness, an important indicator of habitat quality for the majority of geophytic orchid species in the Kimberley, appears to have changed significantly since the advent of pastoralism in the region (Connor *et al.* 2018). Observations of early botanists and explorers (Fitzgerald 1905, 1918; Easton 1922, Gardner 1923) suggest the presence of large areas of palatable perennial grass species on plains now often dominated by annual *Sorghum* species, which are quick to colonise disturbed areas, but there is little quantified data available to understand what these changes have really been, and their broader implications for landscape changes over time.

Rugged sandstone habitats, where many of the Kimberley orchid species occur, are known refugia for fire-sensitive (obligate seeder) species (Russell-Smith *et al.* 1998, 2002; Yates & Russell-Smith 2003) which are being displaced by current fire regimes (Russell-Smith *et al.* 2002; Fisher *et al.* 2003). Frequent fires have been shown to have a significant impact on obligate seeder species of heath habitats in summer rainfall zones (as experienced in the Kimberley) in the Sydney region, including Banksias (Bradstock *et al.* 1997). Similarly, there is an apparent decline in the Kimberley populations of *Banksia dentata,* an indicator species, when growing with *Pandanus* and *Eucalyptus houseana*, for orchid-rich areas in the region (R. Barrett & M. Barrett pers. obs.). While this species is a resprouter following moderate fire, it is suggested that vigour diminishes with high fire frequency, trees can be killed by high-intensity fires, and seedling recruitment is much reduced, leading to overall population decline. This pattern of decline has been well documented for the resprouter tree species *Callitris intratropica* in the Kimberley and Northern Territory (Bowman *et al.* 2001; Fisher *et al.* 2003).

Epiphytic orchid species are often the most vulnerable with loss of plants and degradation of suitable host trees exposed to fire (Koopowitz *et al.* 2003). However, the effects of burning season on flowering should be examined for the geophytic species in the Kimberley region as flowering is known to be inhibited by summer fires in temperate species of *Calochilus* that are summer-flowering (Jones 2021).

Habitats, distribution, and ecological attributes

The underlying geological formation for the region is the Kimberley Block, largely based on quartz sandstone, with smaller areas of basalt and granite intrusions with laterite interspersed (Gunn & Meixner 1998). The sandstone plateaux of the Kimberley have their greatest similarity with that of the World Heritage listed Kakadu National Park in the Northern Territory, and both have a relatively high number of endemic non-orchid plant taxa (Brennan 1986; M. Barrett and R. Barrett unpubl. data). The majority of the sandstone plateaux receive between 800–1400 mm average annual rainfall, mostly falling from January–March. Each of the habitats described below are found in numerous locations across northern Australia which is probably one of the main factors influencing the low endemism in orchid species in the Kimberley region.

Orchids are generally of restricted distribution in the Kimberley region, with only two species being found outside the wettest region of the Gardner Botanical District, with most species being restricted to the West Gardner subdistrict, which corresponds to the highest rainfall zone in the region (Figure 1; and see Wheeler 1992). There is a general lack of published ecological and geographical data on geophytes, especially those occurring in monsoonal rainforest (e.g. data in Kenneally *et al.* 1991), as some species (*Eulophia picta*) are widespread and common, while others are relatively rare (*Habenaria hymenophylla*, *Nervilia holochila* and *Zeuxine oblonga*).

Orchid habitats

A summary of the key habitat characteristics associated with Kimberley orchids is provided below to assist with conservation planning and further searching for additional populations.

- Eucalyptus alba / E. apodophylla / E. houseana – Banksia dentata – Pandanus spiralis *woodland over closed grassland* (Figure 2A)

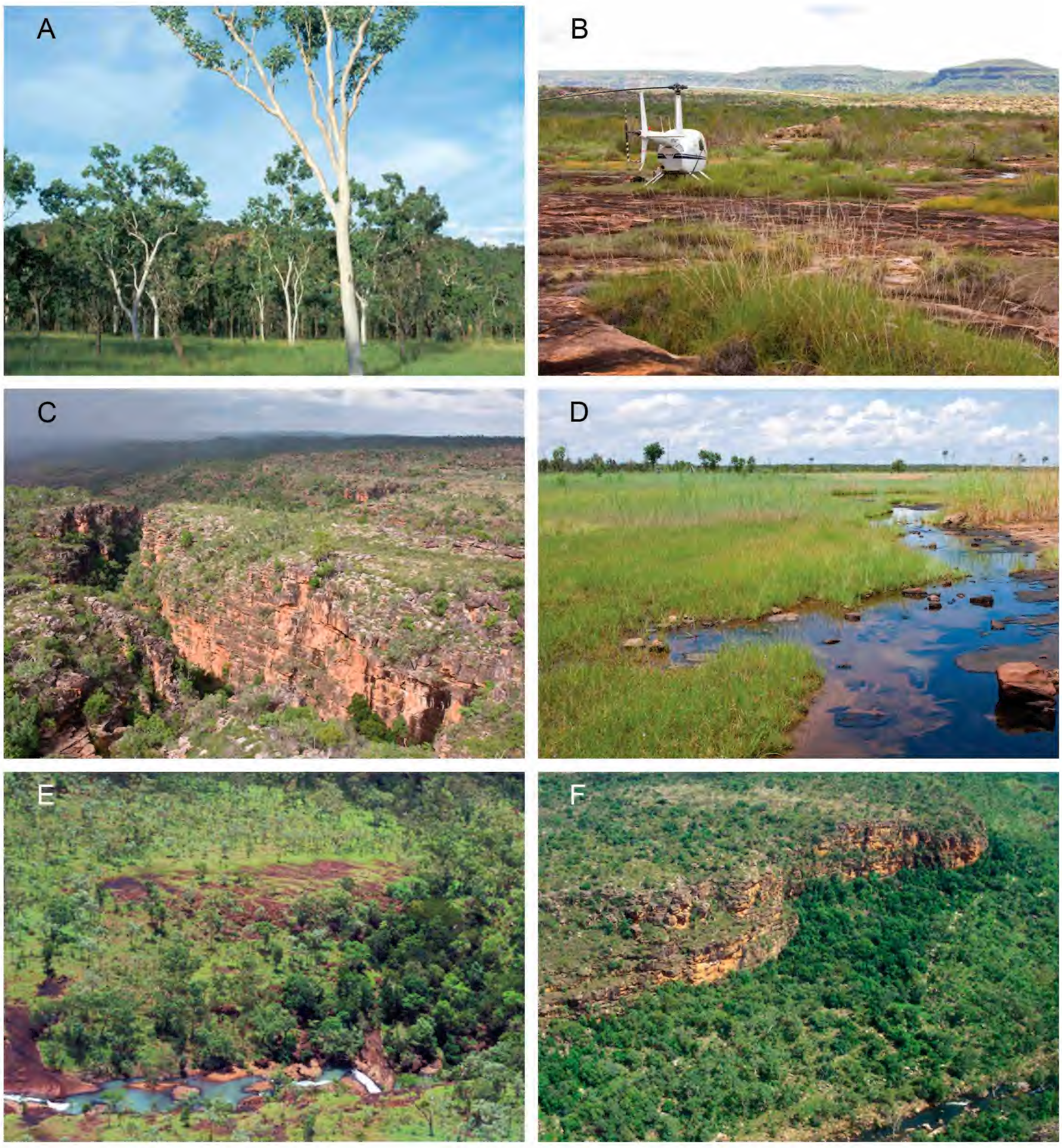

Fig. 2. Habitats of Orchidaceae in the Kimberley Region of Western Australia. A: *Eucalyptus houseana – Banksia dentata* woodland over closed grassland. B: Sandstone pavements. C: Broken sandstone. D: Sand flats derived from sandstone. E: Open woodland on red volcanic clay-loam (with some seasonal waterlogging). F: Vine thickets and rainforest (at base of sandstone cliff).

These open woodlands over dense closed grassland on organic-rich sandy soils are unique assemblages of sporadic occurrence on the sandstone plateaux of the high-rainfall zone of the north-west Kimberley, with similar communities occurring in the Northern Territory. These plant communities occur on seasonally

waterlogged, poorly drained, low-lying flats below sandstone ridges, usually surrounded by either open woodland or open grassland. Higher water tables relative to surrounding areas allow the vegetation to avoid desiccation long into the dry season and early fires are not often carried in these habitats. However, late dry season fire events can be a threat to these habitats when extensive savanna grasses are highly combustible. Most orchid species in this habitat are geophytic, and hence most are not directly threatened by such fires, though fires can be coincident with flowering of *Nervilia holochila* and *Eulophia bicallosa*. Threats come from the risk of post-fire invasion of annual *Sorghum* spp. which are more likely to sustain fire, increasing overall fire frequency, which in turn burns the organic-rich soil surface, over time destroying the orchid habitat (Chen *et al.* 2004).

In some areas these habitats are threatened by feral animals, particularly grazing by cattle and pigs which seek out the root tubers of sedges, grasses and orchids (Figure 3). Uprooting of tubers of *Pecteilis elongata* has been noted on herbarium collections from the Darwin region in the Northern Territory. Feral donkeys and buffalo could also be of concern in some situations. Some orchid habitats with higher stocking rates are known to be churned by cattle hooves and pig wallows (R. Barrett & M. Barrett, pers. obs, R. Maher & B. Maher pers. comm.) and also act as sites for weed invasion.

Fig. 3. Disturbance to orchid-suitable habitat by feral pigs searching for roots and tubers in the Prince Regent National Park.

Overstorey species characterising this habitat type are a combination of *Eucalyptus alba* or *E. houseana*, *Banksia dentata* (a species of restricted distribution that is vulnerable to high frequency or intensity fires with preference for this habitat type), *Eucalyptus apodophylla, Melaleuca viridiflora* and *Pandanus spiralis* (widespread tree or screw palm species common in this habitat type). Orchid species may be more easily located by first locating sites with co-occurring indicator trees.

Understorey species of this habitat vary to some extent, but usually include *Alloteropsis semialata*, *Byblis liniflora*, *Calochilus barbarossa*, *C. kimberleyensis, Clitoria australis*, *Drosera* aff. *paradoxa*, *Eulophia bicallosa* (specific to habitat type), *Haemodorum flaviflorum*, *Lindernia plantaginea, Ludwigia octovalvis*, *Pecteilis eurystoma*, *Scleria brownii, Stylidium pachyrrhizum,* and *Xyris complanata*. Less common understorey species are *Didymoplexis pallens*, *Empusa habenarina* (both restricted to this habitat type), *Hypoxis nervosa, Gonocarpus chinensis, Utricularia kimberleyensis,* and *U. uliginosa*.

- *Grasslands and heaths on sandstone pavements* (Figure 2B)

Sandstone pavements represent a particularly interesting ecological community which for the Kimberley region has only recently been recognised as distinct from the broken quartz sandstone plateaux on which they occur, with many locally endemic species (Barrett & Barrett 2015; Barrett 2018). Pavements are areas of skeletal sands and organic matter over sheet sandstone, usually located on the tops of mesas and plateaux. These habitats also occur on the Kakadu sandstone in the Northern Territory where they often provide habitat for myrtaceous-dominated heath (Brennan 1986, Russell-Smith *et al*. 2002). *Calochilus* spp. and *Phoringopsis byrnesii* are found on these unusual fire-protected sites. The remoteness and fire-protected nature of the pavements indicates they are under little immediate threat. Frequent fire could possibly be a threat on more extensive pavements with higher plant biomass capable of carrying fire (Russell-Smith *et al*. 2002).

Vegetation is often dominated by *Acacia* spp. and *Triodia* spp. with associated vegetation of *Acacia cyclocarpa*, *A. nuperrima*, *Borya subulata*, *Byblis filifolia, B. liniflora*, *Calochilus barbarossa*, *C. kimberleyensis*, *Calytrix gomphrenoides*, *Corymbia torta* subsp. *torta*, *Drosera cucculata, D. glabriscapa, D. paradoxa*, *Eriachne glandulosa*, *Fimbristylis* spp., *Grevillea latifolia*, *G. wickhamii*, *Hypoxis cavernicola, Iphigenia indica, Lechenaultia* aff. *filifolia, Micraira* spp., *Phoringopsis byrnesii*, *Ricinocarpos rosmarinifolius*, *Stylidium ceratophorum*, *Tacca maculata, Thysanotus banksii, Triodia* spp., *Typhonium* aff. *nudibaccatum* and *Utricularia magna*.

- *Woodlands on broken sandstone habitats* (Figure 2C)

A common and widespread habitat type in many areas of northern Australia is broken quartz sandstone and sandstone scree slopes. In the north-west Kimberley, this habitat often includes *Brachychiton viscidulus*, *Corymbia greeniana*, *Corymbia torta* subsp. *torta*, *Cymbopogon procerus*, *Dipodium ammolithum*, *Eucalyptus tetrodonta*, *Ficus platypoda*, *Gardenia* spp., *Goodenia sepalosa*, *Pecteilis elongata*, *Planchonia rupestris*, *Planchonella pohlmaniana*, *Solanum heteropodium*, *Tacca leontopetaloides*, *Terminalia canescens*, *T. ferdinandiana* and *Triodia* spp.

These habitats are in some ways naturally protected from high intensity fire due to the sparse vegetation on the broken sandstone, and the leaf litter between boulders where *Dipodium ammolithum* occurs is largely untouched by fire. Low intensity fires do not appear to have immediate effects on *Dipodium ammolithum* which has been observed flowering readily following fire even where the litter layer has been burnt.

- *Woodlands on sand flats derived from sandstone* (Figure 2D)

Open sandy flats are common below quartz sandstone ridges and alongside creek-lines over sandstone. These sandflats may form shallow depressions, or be lightly sloping alongside creeks, with a catchment area above them which ensures seasonal waterlogging and soil moisture persisting longer than the surrounding soils. Such sandflats occur with sandstone ranges across northern Australia. In the Kimberley region they are commonly dominated by *Fimbristylis* spp. with *Acacia nuperrima, Alloteropsis semialata, Calochilus barbarossa*, *Calochilus kimberleyensis*, *Crinum joesmithii*, *Drosera caduca, D. ordensis*, *Drosera* aff. *paradoxa*, *Grevillea pteridifolia*, *Haemodorum brevicaule*, *H. flaviflorum*, *Hakea arborescens*, *Lindernia plantaginea, Ludwigia octovalvis*, *Melaleuca viridiflora*, *Pandanus darwinensis*, *P. spiralis*, *Pecteilis eurystoma*, *Platyzoma microphyllum*, *Sorghum stipoideum*, *Stylidium pachyrrhizum, S. prophyllum*, *S. rubriscapum*, *Polygala* sp., *Utricularia chrysantha* and *Xyris complanata*.

In more open woodland over sandstone plateaux, *Calochilus holtzei* occurs in direct association with *Corymbia* spp., particularly *C. latifolia* and *C. greeniana* in Western Australia, and *C. foelscheana* in the Northern Territory.

Eucalyptus alba – Banksia dentata woodlands may occur as small pockets on these more extensive sand flats, but the two habitats are here treated as distinct based on vegetation associations, also reflected in differences in organic matter in the soil, and the orchid species that can be found in them.

- *Open woodland on red volcanic clay-loam* (Figure 2E)

Open Eucalypt woodland with the overstorey dominated by *Eucalyptus tetrodonta* with an associated flora of *Erythrophleum* aff. *chlorostachys*, *E. tectifica*, *Pecteilis ochroleuca*, *Livistona eastonii* (in the Mitchell Plateau area), *Murdannia graminea*, *Planchonia careya*, *Sorghum* spp. and *Terminalia canescens*. *Dipodium basalticum* occurs very patchily in this habitat type. Open eucalypt woodland dominated by a variety of *Corymbia* and/

or *Eucalyptus* species provides habitat for *Cymbidium canaliculatum*, even in more extreme environments on the edge of the Tanami desert. *Habenaria ochroleuca* will occasionally occur in darker alluvial soils which are seasonally waterlogged, where it is most commonly found in association with *Melaleuca minutifolia*.

- *Vine thickets and rainforest* (Figure 2F)

Vine thickets in the Kimberley region vary greatly in composition and dominance (Kenneally *et al.* 1991) with many similarities to corresponding areas of the Northern Territory. It is noteworthy that there are clear distinctions in vegetation composition based on substrate, especially those on basalt versus sandstone, but also for spring-fed communities. Orchids in Kimberley vine thickets and rainforest occur most frequently in areas of high humidity but low flow (usually along small creek lines or at cliff bases), with a relatively dense canopy. Associated species (in very mixed combinations) may be *Carallia brachiata*, *Clematis pickeringii*, *Dendrobium dicuphum*, *Diospyros* spp., *Eulophia picta*, *Lophostemon grandiflorus* subsp. *riparius*, *Myristica insipida*, *Nervilia holochila*, *Stenochlaena palustris*, *Syzygium angophoroides*, *Tournefortia mollis*, and occasionally *Cymbidium canaliculatum, Didymoplexis pallens, Dipodium ammolithum, Ficus hispida, Pandanus spiralis* and *Pouteria sericea*.

- *Spring-based swamp vegetation*

Point Springs represents an unusual habitat in the Kimberley, being a small swamp with tall vegetation, including some species typically occurring in rainforest or vine thickets (Kenneally *et al.* 1991). This swamp sits near the base of a sandstone slope, on the margin of extensive blacksoil flats associated with the Ord River. This habitat is the only known location for *Zeuxine oblonga* in the Kimberley. The single known *Spiranthes sinensis* collection was from a grass and sedge dominated mound spring.

Taxonomy and species ecology

Twenty species of orchid in 13 genera are now recognised as occurring in the Kimberley region of Western Australia. A brief history of recent classifications for these species is presented in Table 4, and information on generic typification partly follows Alrich & Higgins (2011) and Mabberley & Moore (2022). A key to these species is provided below to replace the key in Wilson (1992).

Table 4. Classification of Kimberley orchids by subfamilies, tribes and subtribes according to *Genera Orchidacearum* and subsequent modifications as accepted here indicated with their associated reference.

Genera Orchidacearum subfamilies, tribes, subtribes and genera	Subsequent changes	References
Orchidoideae Eaton.		
Diurideae Endl. ex Butzin		
Drakaeinae Schltr.		
37. *Phoringopsis* D.L.Jones & M.A.Clem.	Separated from *Arthrochilus* F.Muell. in 2002	Pridgeon *et al*. 2001; Jones *et al*. 2002; Miller & Clements 2014
Thelymitrinae Lindl.		
53. *Calochilus* R.Br.		Pridgeon *et al*. 2001; Nargar *et al.* 2018
Orchideae Small		
Orchidinae Reveal		
78. *Habenaria* Willd.	Significant redefinition required, see text	Pridgeon *et al*. 2001; Jin *et al*. 2014, 2017; Clements & Jones 2018
90. *Pecteilis* Raf.	Substantially enlarged to include some species previously in *Habenaria*	Pridgeon *et al*. 2001; Jin *et al*. 2014, 2017; Clements & Jones 2018
Cranchideae Pfeiff.		
Goodyerinae Ridl.		
166. *Zeuxine* Lindl.		Pridgeon *et al*. 2003
Spiranthinae Lindl.		
203. *Spiranthes* Rich.		Pridgeon *et al*. 2003
Epidendroideae Lindl.		
Gastrodieae Lindl.		
368. *Didymoplexis* Griff.		Pridgeon *et al*. 2005
Malaxideae Lindl.		
378. *Liparis* Rich. (including *Empusa* Lindl.)	Significant redefinition required, see text	Pridgeon *et al*. 2005; Su *et al*. 2015; Kumar *et al*. 2022
Nervilieae (Schltr.) Dressler		
Nerviliinae Schltr.		

Genera Orchidacearum subfamilies, tribes, subtribes and genera	Subsequent changes	References
392. *Nervilia* Comm. ex Gaudich.		Pridgeon *et al*. 2005
Cymbidieae Pfeizer		
Cymbidiinae Benth.		
447. *Cymbidium* Sw.		Pridgeon *et al*. 2009
448. *Dipodium* R.Br.		Pridgeon *et al*. 2009
Eulophiinae Benth.		
460. *Eulophia* R.Br. ex Lindl.	Significant redefinition required, see text	Pridgeon *et al*. 2009; Bone *et al*. 2015; Chase *et al*. 2021b
462. *Geodorum* Jacks.	Congeneric with *Eulophia*	Pridgeon *et al*. 2009; Bone *et al*. 2015; Chase *et al*. 2021b
Dendrobieae Lindl. ex Endl.		
622. *Dendrobium* Sw.	Significant redefinition may be required, see text	Pridgeon *et al*. 2014; Nargar, Clements, in. prep.

Key to Orchidaceae species in the Kimberley region of Western Australia

1 Plant a leafy epiphyte 2

1: Plant terrestrial, leafy or not 4

2 Leaves stiff and leathery; flowers yellow and purple or green; labellum not spurred..... **Cymbidium canaliculatum**

2: Leaves not leathery; labellum spurred..... **Dendrobium** (3)

3 Flowers with planar tepals, white with a pink or green labellum ..... **Dendrobium dicuphum**

3: Flowers with twisted tepals, white at the base, yellow towards the apex, with a white labellum with prominent red markings..... **Dendrobium foelschei**

4 Leaves with a winged keel, ± Y-shaped in cross-section; labellum conspicuous, entire, not spurred, densely hairy ..... **Calochilus** (5)

4: Leaves pleated or smooth, not Y-shaped in cross-section, or absent; labellum various, not prominently hairy 7

5 Inflorescence with 10–40+ flowers; flowers 20–25 mm long, 8–12 mm wide; leaves more than 10 mm across (usually fully developed, or nearly so, at anthesis); growing in association with *Corymbia* spp..... **Calochilus holtzei**

5: Inflorescence with 2–10 flowers; flowers 11.7–21.4 mm long, 5.2–9.2 mm wide; leaves less than 8 mm wide (sometimes absent at anthesis)..... 6

6 Inflorescences with 2–4 flowers; flowers 11.7–15.6 mm long, 5.2–7.4 mm wide; ovary narrowly ovate (length), labellum tip not concave ..... **Calochilus kimberleyensis**

6: Inflorescences with 6–10 flowers; flowers 18.4–21.4 mm long, 8.1–9.2 mm wide; ovary ovate (length), labellum tip concave..... **Calochilus barbarossa**

7 Leaves present at time of flowering..... 8

7: Plant leafless or leaves not present at time of flowering..... 16

8 Leaves arising on separate stalk from inflorescence, top of flowering spike reflexed in flower, straightening in fruit..... **Eulophia picta**

8: Leaves arising on same stalk as inflorescence, inflorescence straight 9

9 Leaves pleated..... **Empusa habenarina**

9: Leaves smooth 10

10 Labellum not or only weakly spurred 11
10: Labellum deeply three-lobed and with a long spur 13
11 Labellum insectiform, column with two lateral horns ..... **Phoringopsis byrnesii**
11: Labellum not insectiform, column without lateral horns 12
12 Flowers white; inflorescence bracts hairy ..... **Zeuxine oblonga**
12: Flowers pink; inflorescence bracts glabrous ..... **Spiranthes sinensis**
13 Lateral petals two-lobed, the lower lobes similar to the labellum lobes ..... **Habenaria hymenophylla**
13 Lateral petals entire ..... **Pecteilis** (14)
14 Labellum lobes filiform, up to 25 mm long, nectar spur 20–35 mm long ..... **Pecteilis elongata**
14: Labellum lobes less than 20 mm long, nectar spur 8–15 mm long 15
15: Lateral labellum lobes narrowly ovate and recurved ..... **Pecteilis ochroleuca**
15 Labellum lobes filiform, up to 12 mm long, spreading to slightly recurved ..... **Pecteilis eurystoma**
16 Petals and sepals adnate for almost half their length; plant leafless ..... **Didymoplexis pallens**
16: Petals and sepals free; plant leafless, or leaves not present during flowering 17
17 Labellum tubular to convex, not spurred; leaves ovate to broadly ovate, emerging after flowering ..... **Nervilia holochila**
17: Labellum with or without a small spur at base; leaves narrowly lanceolate or absent 18
18 Labellum convex, shallowly 3-lobed at the apex, with a small spur at base; leaves present after flowering time, narrowly lanceolate ..... **Eulophia bicallosa**
18: Labellum flat, entire, not spurred at the base; plant obligately mycotrophic and leafless ..... **Dipodium** (19)
19 Petals not spotted; growing on sandstone outcrops ..... **Dipodium ammolithum**
19: Petals obscurely spotted and streaked; growing in open woodland on basalt soils ..... **Dipodium basalticum**

Species treatments

Calochilus R.Br., *Prodr*. 320 (1810). *Lectotype*: *C. paludosus* R.Br., designated by M.A.Clements, *Austral. Orchid Res*. 1: 35 (1989).

A predominantly Australian genus comprising some 28 species divided into three subgenera only one of which subgen. *Tropichilus*, is represented in tropical Australia (Nargar *et al*. 2018).

Subgenus **Tropichilus** M.A.Clem., *Australian Systematic Botany* 31: 405-406 (2018). *Type species*: *Calochilus caeruleus* L.O.Williams.

Calochilus sect. *Pulchrichilos* Szlach., *Polish Bot. J*. 46(1): 13 (2001).

Column apex cucullate and bulbous. Labellum with calli that form one or two ridged plates or two prominent tooth-like protrusions, staminodia visible as appendages, stem bracts not covering the ovary. In rare peloric forms flowers cleistogamous and labellum without calli.

Notes: Following the description of the first tropical *Calochilus* species, *C. holtzei* F.Muell. (Mueller 1892), new tropical species have been named by Williams (1946), Jones & Lavarack (1989), Jones & Gray (2002) and Jones & Clements (2004).

The three Kimberley species can be distinguished by the characteristics detailed in Table 5.

Table 5. Comparison of key features in Kimberley *Calochilus* species.

	C. barbarossa	*C. holtzei*	*C. kimberleyensis*
Leaves	narrow, 1.5-3 mm wide	broad, 12-15 mm wide	narrow, 1.5-3 mm wide
No. Flowers	6–10	10–40+	2–4
Flower size	18.4–21.4 mm long, 8.1–9.2 mm wide	20–25 mm long, 8–12 mm wide	11.7–15.6 mm long, 5.2–7.4 mm wide
Capsule size	9–12 mm long, 3–4.5 mm wide	11–16 mm long, 4.8–7.4 mm wide	12–19 mm long, 3.3–4.5 mm wide
Column wing glands	many, minute	many, minute	1, minute
Labellum hair colour	red, lacking purple tints	orange, lacking purple tints	red with vinaceous tints
Labellum lateral hairs	greatly exceeding margin	greatly exceeding margin	scarcely exceeding margin
Labellum base	unequally haired	unequally haired	equally haired
Labellum apex	rounded	triangular	truncate
Lateral sepal markings	*c.* 5 prominent red veins	*c.* 7 prominent red veins	diffuse red, *c.* 3 obscure veins just detectable
Flowering time	mid Dec.–early Feb.	late Jan.–Feb.	late Dec.–early Feb.

Calochilus barbarossa R.L.Barrett, M.D.Barrett and K.W.Dixon, *sp. nov.*

Type: Western Australia: Edkins Range, on Walcott Inlet track, 79 km N of Beverley Springs Station homestead, 10 Jan. 1995, *R.L.Barrett* & *M.D.Barrett RLB 908* (holo: PERTH; iso: CANB, NSW).

Illustrations: A.P.Brown *et al.*, *Orchids West. Austr.*, pl. p. 363 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 478, 479, 481 (2013). D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); pl. p 420 (2021), as *C. caeruleus*, NT only.

Erect geophytic *herb*, tubers ovoid, 1.8–2.7 cm long, 0.8–1.5 cm wide, fleshy. *Leaves* usually partially to well-developed at anthesis, linear, triquetrous in cross-section, erect, dark green, fleshy, margins bluntly rounded, apex acute, 15–30 cm long, 1.5–3 mm wide. *Inflorescence* 300–700 mm tall, very slender, dull green or glaucous; sterile bracts 2–5, lanceolate, 7.5–35 mm long, 2.3–4.5 mm wide, closely sheathing, subacute; fertile bracts lanceolate, 6.0–6.9 mm long, 1.4–2.1 mm wide, closely sheathing, acute. *Pedicels c.* 9.1 mm long, slender, obliquely erect. *Flowers* lasting about half a day, (3–)6–10, 18.4–21.4 mm long, 8.1–9.2 mm wide; perianth segments spreading widely at temperatures above *c.* 25°C, obliquely erect. *Dorsal sepal* obovate, 7.6–8.1 mm long, 4.3–4.8 mm wide, cucullate, concave, gibbous towards base, pale green with dark reddish marks near the base on the anterior surface, acute. *Lateral sepals* asymmetrically broadly lanceolate, 7.2–7.9 mm long, 3.2–3.4 mm wide, widely divergent, slightly carinate, subacute to apiculate. *Petals* narrowly ovate-lanceolate, 7.0–7.2 mm long, 2.3–3.1 mm wide, asymmetrical, obliquely deflexed close to the lateral sepals, tips slightly incurved, with many dark red lines on the anterior surface, obtuse to subacute. *Labellum* projected obliquely downwards, oblong-elliptical, 14.3–16.5 mm long, 5.5–6.0 mm wide, cupped or saccate towards the apex, obscurely 3-lobed, the margins of the lateral lobes with 5–7 pairs of very short, linear teeth, apex sub-acutely apiculate; ventral surface pale yellow-green with reddish spots or streaks, the proximal two-thirds densely adorned with appressed curved, linear-terete, deep reddish to purple calli 1.7–4.0 mm long, the distal third devoid of calli; basal pair of labellum calli only moderately raised, *c.* 1.6 mm long, 0.3 mm wide, fleshy, slightly incurved, pinkish-red, shiny; dorsal surface pale yellow-green. *Column* 4.6–5.3 mm long, 2.9–3.5 mm wide, green, strongly gibbous and glandular-papillate beneath the anther; wings broad, obtuse, protruding, with a few small purple spots. *Anther* 2.7–3.6 mm long, 1.5–2.1 mm wide, green with cream flaps, obliquely erect, surface minutely colliculate. *Pollinia* 2.0–2.3 mm long, curved, cream to white, mealy. *Stigma* oblong, 1.4–1.8 mm across, sunken. *Capsule* narrowly ovoid, 9–12 mm long, 3–4.5 mm wide, ribbed. (Figure 4)

Diagnostic characters: Related to *C. caeruleus*, distinguished by the lateral ridges at base of labellum very pale purplish (*vs* very dark purplish), extending only half-way to free calli (to the start of free calli in *C. caeruleus*), and long, slightly saccate, bare lip on the labellum (bare portion short and not saccate in *C. caeruleus*), with consistently purplish red hairs at the base of the labellum (bluish in *C. caeruleus*). The narrower leaves (1.5–3 vs 6–8 mm wide) are partially to fully developed at anthesis. The inflorescence has generally fewer flowers ((3–)6–10 vs 4–12). Flowers remain open for most of the day.

Fig. 4. *Calochilus barbarossa*. A. Habit. B, C. Flower. D. Capsule. E. Leaves at advanced anthesis. F. Close-up of leaf. G. Inflorescence. H. Close-up of flower. I. Close-up of labellum apex. J. Lateral view of flower showing saccate labellum. Voucher: *R.L.Barrett, M.D.Barrett & M.Maier RLB 6158* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Specimens examined: WESTERN AUSTRALIA: 6 km ENE of junction of Pitta Creek and Prince Regent River, 29 Jan. 2000, *M.D.Barrett* MDB 962 (PERTH); 2.7 km NW of Mt Hann, 31 Jan. 2000, *M.D.Barrett* MDB 1030 (PERTH); Edkins Ra., 79 km N of Beverley Springs Stn Hstd, 10 Jan. 1994, *R.L.Barrett* & *M.D.Barrett* RLB 966 (PERTH); Edkins Ra., 77 km N of Beverley Springs Stn Hstd, 28 Dec. 1995, *R.L.Barrett* & *M.D.Barrett* RLB 674 (PERTH); 1 km NW of Mount Bomford, 5 Jan. 2001, *R.L.Barrett* & *M.D.Barrett* RLB 1538 (CANB, PERTH); *c.* 8.5 km NE of Mount Agnes, 6 Jan. 2001, *R.L.Barrett* RLB 1574 (CANB, PERTH); 1 km NW of 'Leptospermum Falls', Prince Regent Nature Reserve, 10 Jan. 2001, *R.L.Barrett* RLB 1662 (CANB, PERTH); 6.5 km NE of junction of Pitta Creek and Prince Regent River, W of Reserve boundary, 10 Jan. 2001, *R.L.Barrett* RLB 1717 (CANB, PERTH); 26.7 km E of Kings Cascades; 12.4 km NNE of junction of Youwanjela Creek and Prince Regent River, Prince Regent Nature Reserve, 25 Jan. 2007, *R.L.Barrett* & *M.D.Barrett* RLB 3839 (PERTH); 6.5 km NE of junction of Pitta Creek and Prince Regent River, W of Reserve boundary, 28 Jan. 2007, *R.L.Barrett* & *M.D.Barrett* RLB 4026 (PERTH); East Isoetes Pavement 1, Prince Regent Nature Reserve, 16 Jan. 2010, *R.L.Barrett, M.D.Barrett & M.Maier* RLB 6158 (PERTH); Gutter Swamp site, N of Bachsten Gorge, Prince Regent National Park, 13 Mar. 2014, *R.L.Barrett* RLB 9007 (PERTH). NORTHERN TERRITORY: *15 km S of Snake Bay, Melville Island, 31 Jan. 1984, *D.L.Jones 1290* (DNA); Emau Plains, Melville Island, 6 Dec. 1984, *D.L.Jones 1691* (DNA); *Emau Plains, Melville Island, 6 Dec. 1984, *D.L.Jones 1692* (DNA). (* at start of location indicates specimens cited by Jones & Clements 2004 as *C. caesius*).

Distribution: Relatively common in the Prince Regent River to Edkins Range area, also extending north to Theda Station and scattered on Melville Island in the Northern Territory.

Conservation status: Widespread and not immediately threatened, though its habitat is increasingly threatened through disturbance by feral pigs (B. Maher, R.L. & M.D. Barrett, pers. obs.).

Ecology: Grows on seasonally wet, shallow sand lenses over sandstone with *Acacia richardsii*, *Byblis filifolia, Borya subulata*, *Drosera cucullata*, *Drosera fragrans, Lechenaultia* aff. *filiformis, Phoringopsis byrnesii*, *Ricinocarpos rosmarinifolius*, *Stylidium ceratophorum*, *Triodia* spp. and *Utricularia magna*.

Phenology: Flowers December–January.

Etymology: From Holy Roman Emperor Barbarossa (1122–1190), ('red beard' in Italian), in reference to the conspicuous beard of red labellum hairs characteristic of this species.

Notes: Wilson (1992) stated that the type description of *C. caeruleus* records this species as being leafless in habit. Leaves of *C. barbarossa* do not appear until part way through anthesis, and the same appears to be true for *C. caeruleus* (Jones 2006; 2021). The concept of *C. caesius* of Jones (2004) also includes some material of *C. barbarossa* and the figure of *C. caeruleus* from the Northern Territory on page 420 of Jones (2021) also represents *C. barbarossa*. The type of *C. caesius* represents a smaller species more closely allied to *C. kimberleyensis*. *Calochilus caesius* is here considered endemic to the Northern Territory.'

C. barbarossa often grows with *C. kimberleyensis* in the Kimberley, but the flowering season only just overlaps, and no intermediates have ever been found. The number of flowers and capsule length are the best features to use when distinguishing dried or fruiting specimens.

Pseudocopulation by scoliid wasps has been observed for this species (M Barrett and R. Barrett, pers. obs.).

Common name: Red beard orchid.

Calochilus holtzei F.Muell., *Vict. Nat.* 8(2): 180 (Mar. 1892); & *Bot. Centralbl.* 50: 127 (1892). *Type*: Northern Territory: near Port Darwin, 1891, *M.Holtze* 1276 (holo: MEL 615533; iso: K 000827519).

Calochilus holtzei var. *obligacocca* J.Simmonds, *The Orchadian* 6: 85 (1979), *nom. nud.*

?*Calochilus imperiosus* D.L. Jones, *The Orchadian Sci. Suppl.* 14(8): v (2004). *Type*: Queensland, Cook District: Shiptons Flat, S. of Cooktown, 30 Mar. 1993, *C.H.Broers* 406 & *L.J.Roberts* (holo: CBG 9306358).

Illustrations: P.Lavarack & B.Gray, *Trop. Orchids Austr.* pl. 15 (1985); D.L.Jones, *Native Orchids Austr.* 311, fig. p. 311 (1988); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1005, fig. 303a (1992); A.Dockrill, *Austr. Indig. Orchids* (edn. 2); 1: 162, fig. p. 163 (1992); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 2); 264, pl. (2006); A.P.Brown *et al.*, *Orchids West. Austr.*, pl. p. 361 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 475, 480 (2013); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 421 pl., 422, fig. (2021).

Erect geophytic *herb*, tubers ovoid, 3–4 cm long, 1.2–1.5 cm wide, fleshy. *Leaves* well developed at anthesis, linear, triquetrous, Y-shaped in cross-section, erect, dark green, somewhat leathery, margins angular, apex acute, 25–50 cm long, 12–20 mm wide. *Inflorescence* 50–100 cm tall, robust, glaucous or dull green; sterile bracts 2 or 3, lanceolate, 2.4–5 cm long, 10–14 mm wide, closely sheathing, acuminate; fertile bracts lanceolate to obovate, 8.4–13.9 mm long, 2.2–3.9 mm wide, closely sheathing, acute to acuminate. *Pedicels* 10–18 mm long, slender, obliquely erect. *Flowers* lasting all day unless fertilised, 10–40+, 20–25 mm long, 8–12 mm wide; outer tepals pale greenish yellow with brown lateral striping; labellum dark purple-brown at base, calli pale greenish yellow at base, variously green, brown or reddish at the apices; perianth segments spreading widely, obliquely erect. *Dorsal sepal* ovate, 7.3–9.4 mm long, 4.5–5.2 mm wide, cucullate, concave, gibbous towards base, green with a few dark lines on the anterior surface, acute. *Lateral sepals* asymmetrically lanceolate to obovate, 6.7–9.1 mm long, 3.2–3.6 mm wide, widely divergent, slightly carinate, acute. *Petals* oblong to obovate, 6.4–8.2 mm long, 2.7–3.2 mm wide, minutely verrucose on underside, asymmetrical, obliquely deflexed close to the lateral sepals, tips slightly incurved, with a few lines on the anterior surface, obtuse. *Labellum* projected obliquely downwards, ovate to oblong, 15–20 mm long, 7–12 mm wide, undulating, minutely verrucose on distal third, glabrous at base with 2 raised keels 2–4 mm long, densely bearded with hairs up to 3.1 mm long and a band of shorter hairs (up to 0.5 mm long) along centre line, glabrous for 2–3 mm at apex, apex acute and recurved, margins upturned to give a triangular appearance. *Column c.* 4 mm long, *c.* 4.2 mm wide, green, strongly gibbous and glandular-papillate beneath the anther; wings broad, obtuse, protruding, with a few small purple spots. *Anther c.* 3 mm long, *c.* 1.5 mm wide, green with cream flaps, obliquely erect, surface minutely colliculate. *Pollinia c.* 2 mm long, curved, cream to white, mealy. *Stigma* oblong, *c.* 1 mm across, sunken. *Capsule* ovoid to broadly ovoid, 11–16 mm long, 4.8–7.4 mm wide, ribbed. (Figure 5)

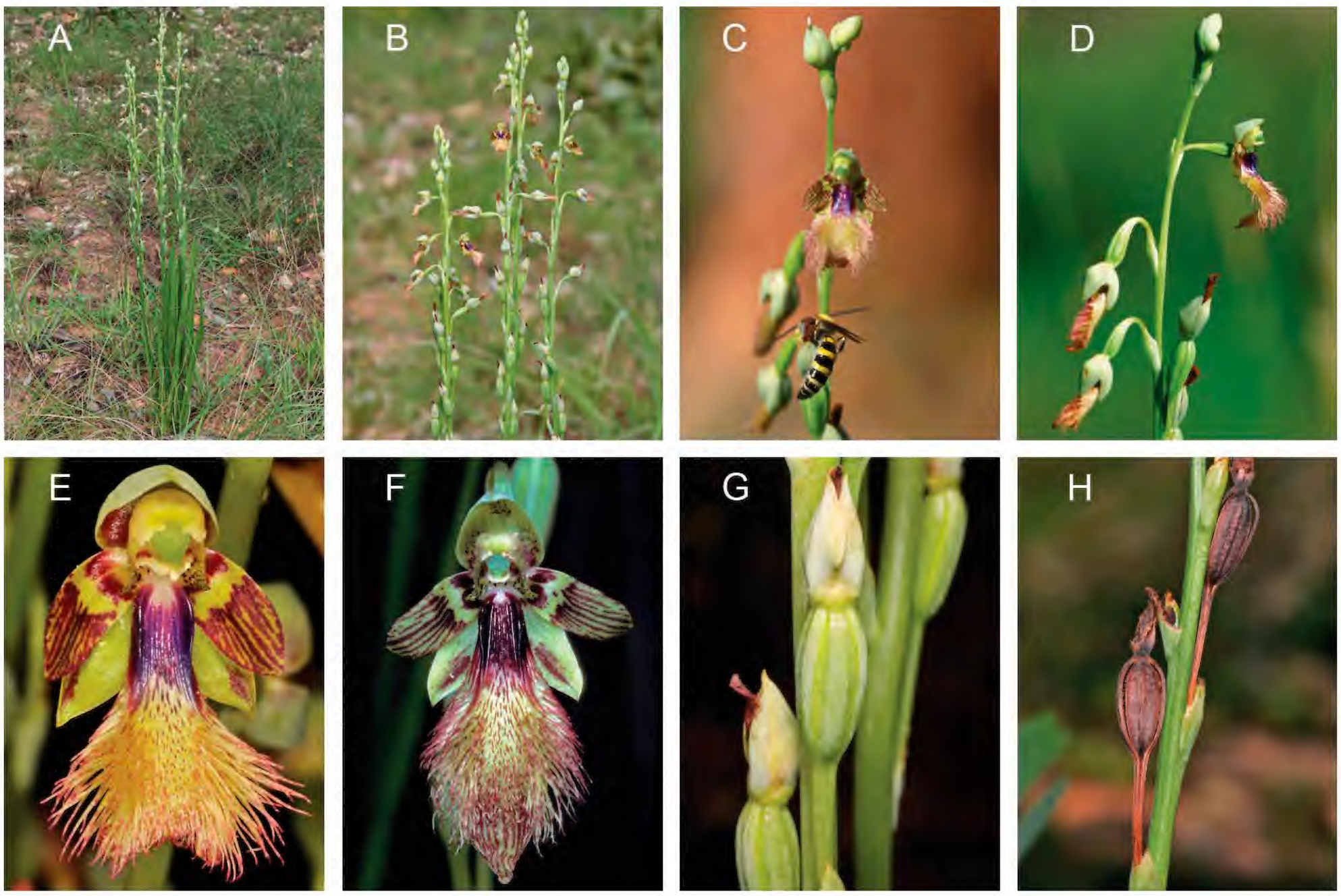

Fig. 5. *Calochilus holtzei*. A. Habit. B. Inflorescences. C. Flower being pollinated by a scoliid wasp (*Radumeris radula*). D. Inflorescence with open flower and developing fruit. E, F. Flowers showing variation in colour between populations. G. Developing fruit. H. Dehisced fruit. Vouchers: A, B, D, E, G, H. *R.L.Barrett, M.D.Barrett & M.Maier RLB 6490* (PERTH). C. *R.L.Barrett RLB 1749* (CANB, PERTH); *F.M.D.Barrett MDB 930* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Specimens examined: WESTERN AUSTRALIA: 15 km N of Junction of Youwanjela Creek and Prince Regent River, 27 Jan. 2000, *M.D.Barrett MDB 922* (PERTH); 3 km SW of Mount Fyfe summit, Drysdale Station, 28 Jan. 2000, *M.D.Barrett MDB 930* (PERTH); 1 km E of Beverley Springs Stn Hstd, 2 Feb. 1995, *R.L.Barrett RLB 976* (PERTH); Synnot Ra., 21 km NW of Beverley Springs Stn Hstd, 7 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 694* (PERTH); Synnot Ra., 32 km NW of Beverley Springs Stn Hstd, 14 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 704* (PERTH); Walgumungun Creek, 1 km E of Beverley Springs Stn Hstd, 31 Jan. 1996, *R.L.Barrett RLB 758* (PERTH); Walgumungun Creek, 1 km E of Beverley Springs Stn Hstd, 2 Feb. 1995, *R.L.Barrett RLB 976* (PERTH); 3 km SW of Mount Fyfe, 11 Jan. 2001, *R.L.Barrett RLB 1749* (CANB, PERTH); 9.8 km ENE of Jameison Arch; 6.6 km SE of Mount Agnes, Mount Elizabeth Station, N of Munja track, 28 Jan. 2007, *R.L.Barrett* & *M.D.Barrett RLB 4044* (PERTH); 2 km S of Bachsten Creek Camp, Edkins Range, 26 Jan. 2010, *R.L.Barrett, M.D.Barrett & M.Maier RLB 6490* (PERTH); cultivated, Botany Dept, UWA, Nedlands ex Mitchell Plateau, N Kimberley**,** 31 Jan. 1980, *K.W.Dixon s.n.* (PERTH); Mitchell Plateau adjacent to Airfield swamp, NW Kimberley, 5 Feb. 1979, *K.F.Kenneally* 7018 (CANB, K, L, PERTH); NE of Airfield swamp, Mitchell Plateau mining camp, 10 Jan. 1979, *J.Smith s.n.* (PERTH 258458). NORTHERN TERRITORY: Kapalga, 30 Dec. 1983, *C.R.Dunlop 6620* (CANB, DNA, MEL, NSW); Howard River headwaters, 6 Apr. 1984, *D.L.Jones 1568* (DNA); Q213; approx. 17 miles N of Oenpelli Mission, 15 Feb. 1973, *M.Lazarides 7715* (CANB); Hanguana Jungle, Melville Island, 26 Nov. 1989, *E.R.Petherick & J.Russell-Smith 8140* (DNA). QUEENSLAND: Davies Creek Rd, upstream of Davies Creek Falls, Mareeba district, 22 Apr. 1981, *P.D.Hind 2930* (NSW); Shiptons Flat, 8 Feb. 1991, *L.Roberts DLJ 7350* (CBG).

Distribution: From Charnley River (formerly Beverley Springs) Station homestead north to the Mitchell Plateau and Theda Station and east to the Northern Territory and Cooktown in Queensland.

Conservation status: Widespread and common in some areas, though inconspicuous and rarely seen. Not considered threatened. This species is conserved in the Prince Regent National Park.

Ecology: Grows exclusively in association with *Corymbia* spp., particularly *C. latifolia*, *C. foelscheana* and *C. greeniana*, on sand over sandstone, beside creeks and on plateau-top flats, often with *Erythrophleum* aff. *chlorostachys* over *Alloteropsis semialata*, *Bossiaea bossiaeoides*, *Chrysopogon fallax* and *Sorghum plumosum*.

The nature of the association between *C. holtzei* and *Corymbia* deserves further exploration, especially in relation to symbiotic fungi.

Phenology: Flowers December–January, with a longer flowering period than other species due to its robust nature and large number of flowers per inflorescence.

Affinities: A very distinctive, robust species that has some of the tallest inflorescences in the genus, making it more visible among tall grasses when they develop later in the wet season. *Calochilus holtzei* is perhaps morphologically closest to *C. barbarossa*, sharing the elongated ridges on the base of the labellum. Phylogenetic analyses by Nargar *et al.* (2018) recovered *C. holtzei* as sister to *C. caeruleus*, but *C. barbarossa* was not included in that study. Jones in Jones and Clements (2004) named *C. imperiosus* based on Queensland specimens previously included within the concept of *C. holtzei*. The differences given appear slight, and the colour of the labellum hairs is quite variable among Kimberley populations, the variation encompassing Jones' (2004) stated differences between taxa. Results from a recent molecular analyses of *Calochilus* did not separate these two species (Nargar *et al.* 2018). We therefore tentatively synonymise the two species, until such time as definitive differences can be identified.

Notes: The only collection for Western Australia prior to the 1990s was from the Mitchell Plateau. This species is now known to be widespread in WA from Theda Station, Mitchell Plateau, the Edkins Range and Beverley Springs (now Charnley River) Station.

Pseudocopulation has been observed for this species. Graham Brown (pers. comm.) has identified the wasp as *Radumeris radula* (formerly *Campsomeris radula*), Scoliidae. (Figure 2C).

Common names: Tall beard orchid, Ghostly beard orchid.

Calochilus kimberleyensis R.L.Barrett, M.D.Barrett & M.A.Clem., *sp. nov*.

Type: Western Australia: Edkins Range, on Walcott Inlet track, 77 km N of Beverley Springs Station Homestead, 16°01'25"S, 125°18'55"E, 28 Dec. 1995, *R.L.Barrett & M.D.Barrett RLB 674* (holo: PERTH; iso: CANB, DNA, NSW).

Calochilus caesius auct. non D.L. Jones: A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 358, 361 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 478, 479 (2013).

Calochilus sp. A Kimberley Flora (K.F. Kenneally 7110), A.J.G.Wilson in J.R.Wheeler (ed.) Fl. Kimb. Reg., 1006, fig. 303b (1992); Western Australian Herbarium. (1998–). FloraBase – The Western Australian Flora. Department of Environment and Conservation. http://florabase.dpaw.wa.gov.au/ [accessed February 2012].

Illustrations: A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 358, 361 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 478, 479 (2013), as *C. caesius*.

Erect geophytic *herb*, tubers ovoid, 1.5–2 cm long, 0.8–1.2 cm wide, fleshy. *Leaves* short or absent at anthesis, linear, triquetrous in cross-section, erect, dark green, fleshy, margins bluntly rounded, apex acute, 10–25 cm long, 2–4 mm wide. *Inflorescence* 200–400 mm tall, very slender, dull green; sterile bracts 2–3, lanceolate, 0.8–2.9 cm long, 1.6–2.6 mm wide, closely sheathing, subacute; fertile bracts lanceolate, 3.6–7.5 mm long, 1.6–2.2 mm wide, closely sheathing, subacute. *Pedicels* 5.5–9.9 mm long, slender, obliquely erect. *Ovaries* 7.3–12.4 mm long, 1.4–1.8 mm wide at flowering. *Flowers* lasting about half a day, 1–3, 11.7–15.6 mm long, 5.2–7.4 mm wide; outer tepals pale yellowish green with purple-brown markings; labellum brownish with deep reddish to purple glossy calli; perianth segments spreading widely at temperatures above *c.* 25°C, obliquely erect. *Dorsal sepal* ovate, 5.2–6.0 mm long, 3.1–4.2 mm wide, cucullate, concave, gibbous towards base, green with a few dark lines on the anterior surface, acute. *Lateral sepals* asymmetrically broadly lanceolate, 4.8–6.0 mm long, 2.0–2.4 mm wide, widely divergent, slightly carinate, acute to apiculate. *Petals* ovate, 4.4–6.2 mm long, 1.7–2.3 mm wide, asymmetrical, obliquely deflexed close to the lateral sepals, tips slightly incurved, with a few lines on the anterior surface, acute. *Labellum* projected obliquely downwards, obovate to oblong-elliptical, 10.1–14.5 mm long, 4.3–6.7 mm wide, flat, very obscurely 3-lobed, the margins of the lateral lobes with *c.* 10 pairs of very short, linear teeth, apex acute; ventral surface reddish brown, the proximal three-quarters densely adorned with appressed curved, linear-terete, reddish calli 0.4–1.7 mm long, the distal eighth devoid of calli; basal pair of labellum calli prominently raised, tooth-like *c.* 2 mm long, 0.5 mm wide, fleshy, shallowly incurved, reddish, shiny; dorsal surface dark reddish brown, finely glandular-dotted. *Column* 3.2–3.5 mm long, 3.0–3.2 mm wide, green, strongly gibbous and glandular-papillate beneath the anther; wings broad, obtuse, protruding, with a few small purple spots and two small sham-eyes at the base. *Anther c.* 1.4 mm long, *c.* 1.6 mm wide, green with cream flaps, obliquely erect, surface minutely colliculate. *Pollinia c.* 1.6 mm long, curved, cream to white, mealy. *Stigma* oblong, *c.* 1.3 mm across, sunken, appendage bluntly triangular. *Capsule* narrowly ovoid, 12–19 mm long, 3.3–4.5 mm wide, ribbed. (Figure 6)

Fig. 6. *Calochilus kimberleyensis*. A. Habit. B. Inflorescence. C–G. Flowers. H. Fruit. I. Lateral view of flower. J, K. Comparison of flowers of *C. barbarossa* (left) and *C. kimberleyensis* (right). Vouchers: A, B, D, F, G, H, I: *R.L.Barrett, M.Maier & P.Kendrick RLB 6238* (PERTH); C, E: *R.L.Barrett RLB 1718* (PERTH); J, K: *R.L.Barrett, M.D.Barrett & M.Maier RLB 6158* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Diagnostic characters: Related to *C. caesius* D.L.Jones but differs by the overall stronger, bolder red colouration of the labellum with vinaceous tints (pale pink-purple in *C. caesius*); labellum slightly crenulated and jagged margin of the labellum apex (± entire in *C. caesius*), dark red-purple when fresh (green with blue-grey colour sheen of the labellum in the light in *C. caesius*); column broader at the base; ovate rather than narrowly ovate-lanceolate petals. Also related to *C. caeruleus*, differing in the smaller flowers and only 2–4 flowers per inflorescence (4–12 in *C. caeruleus*).

Specimens examined: WESTERN AUSTRALIA: *c.* 1 km E of falls at head of N arm of Bachsten Creek, Prince Regent River Reserve, 30 Jan. 1999, *M.D.Barrett MDB 668A* (PERTH); 1/3 way uphill on jump-up on Beverley Springs–Walcott track, N end of Edkins Range, 5 Feb. 1999, *M.D.Barrett MDB 785* (PERTH); Edge of plateau above upper Prince Regent River, 3.5 km E of Mount Agnes, 2 Feb. 2000, *M.D.Barrett MDB 1038* (PERTH); Edkins Ra., 74 km N of Beverley Springs Stn Hstd, 26 Dec. 1995, *R.L.Barrett & M.D.Barrett RLB 638* (CANB, NSW, PERTH); Edkins Ra., 79 km N of Beverley Springs Stn Hstd, 9 Jan. 1995, *R.L.Barrett & M.D.Barrett* RLB 906 (PERTH); Edkins Ra., 11 Jan. 1995, *R.L.Barrett & M.D.Barrett RLB 907* (PERTH); *c.* 8.5 km ENE of Mount Agnes, 6 Jan. 2001, *R.L.Barrett RLB 1570* (PERTH); *c.* 8 km N of Charnley River Crossing on Walcott Inlet track, Edkins Ra., 8 Jan. 2001, *R.L.Barrett & K.W.Dixon RLB 1657* (PERTH); 6.5 km NE of junction of Pitta

Creek and Prince Regent River, W of Reserve boundary, 10 Jan. 2001, *R.L.Barrett RLB 1718* (PERTH); gutter swamp site, north of Bachsten Creek Falls, Prince Regent Nature Reserve, 18 Jan. 2010, *R.L.Barrett, M.Maier & P.Kendrick RLB 6238* (PERTH); Sandstone pavement E of Mount Brookes, Prince Regent Nature Reserve, 19 Jan. 2010, *R.L.Barrett, M.Maier & P.Kendrick RLB 6273* (PERTH); gutter swamp site, north of Bachsten Creek Falls, Prince Regent Nature Reserve, 13 Mar. 2014, *R.L.Barrett RLB 9006* (PERTH); swamp N of fuel dump which is N of Amax Basecamp, NW Kimberley, 9 Feb. 1979, *K.F.Kenneally 7110* (PERTH).

Distribution: West and Central Gardner districts, Northern Botanical Province (Beard 1990), recorded from the Edkins Range, Prince Regent National Park, Mitchell Plateau, Theda and Doongan (King Edward River) Stations in the Kimberley.

Ecology: Sandy flats over sandstone in seasonally damp areas. Growing in association with *Acacia dunnii*, *A. nuperrima*, *Banksia dentata*, *Byblis liniflora*, *Calochilus barbarossa*, *Clitoria australis*, *Didymoplexis pallens*, *Drosera caduca*, *D. ordensis*, *D.* aff. *paradoxa*, *Erythrophleum* aff. *chlorostachys*, *Eucalyptus alba*, *E. apodophylla*, *E. tetrodonta*, *Eulophia bicallosa*, *Grevillea pteridifolia*, *Haemodorum flaviflorum*, *Hakea arborescens*, *Hypoxis nervosa*, *Lindernia plantaginea*, *Empusa habenarina*, *Ludwigia octovalvis*, *Melaleuca viridiflora*, *Pandanus spiralis* var. *spiralis*, *Pecteilis eurystoma*, *Platyzoma microphyllum*, *Stylidium pachyrrhizum*, *Triodia* sp., *Polygala* sp. and *Xyris complanata*.

Phenology: Flowers December–early February.

Conservation status: This species is widespread in distribution and common in limited populations. It is not considered to be under any threat at present, though some populations are disturbed by pigs. The range of this species includes the Prince Regent National Park.

Etymology: The epithet refers to the Kimberley region where this species is apparently endemic.

Notes: This species was referred to as *Calochilus* sp. A by Wilson (1992). Results from molecular analysis of 80 plastid loci and one nuclear locus (ITS) including, *C. caesius* collected from the Northern Territory and *C. kimberleyensis* from the Kimberley confirmed their sister relationship (Nargar *et al.* 2018). Descriptions and photos of *C. caesius* can be found in Liddle *et al.* (2017) and Jones (2021).

First discovered in the north Kimberley by Kevin Kenneally in February 1979.

Common name: Kimberley beard orchid.

Cymbidium Sw., *Nova Acta Regiae Soc. Sci. Uppsal.* ser. 2, 6: 70 (1799). *Lectotype*: *Cymbidium aloifolium* (L.) Sw., designated by P.F.Hunt, *Kew Bull.* 24(1): 94 (1970).

Jensoa Raf., *Fl. Tellur* 4: 38 (1836). *Lectotype*: *J. ensata* (Thunb.) Raf., *nom. illeg.*, designated by P.F.Hunt, *Kew Bull.*, 24(1): 94 (1970).

Cyperorchis Blume, *Rumphia* 4: 47 (1848). *Type*: *C. elegans* (Lindl.) Blume, designated by P.F.Hunt, *Kew Bull.*, 24(1): 94 (1970).

Iridorchis Blume, *Orchid. Arch. Ind.* 1: 91, t. 26 (1858). *Type*: *Cymbidium giganteum* Wall. ex Lindl.

Arethusantha Finet, *Bull. Soc. Bot. France* 44: 178–180, t. 15 (1897). *Type*: *Arethusantha bletioides* Finet.

× *Cyperocymbidium* A.Hawkes, *Orchid Rev.* 72: 420 (1964). *Type*: Not designated.

Notes: The genus *Cymbidium* is well-defined and two editions of a generic monograph have been published (Du Puy & Cribb 1988, 2007). Some phylogenetic relationships of Cymbidiinae genera have been questioned by Batista *et al.* (2014), but largely clarified by more extensive sampling by Li *et al.* (2016) and Zhang *et al.* (2019). Relationships within *Cymbidium* have been assessed by Zhang *et al.* (2002) who questioned the existing subgeneric classification. Additional sampling by Lan *et al.* (2018) supports the recognition of three subgenera.

Subgen. **Cymbidium**

Section **Cymbidium**

Section *Austrocymbidium* Schltr., *Repert. Sp. Nov. Regni Veg.* 20: 104 (1924). *Lectotype*: *C. canaliculatum* R.Br., designated by P.Hunt, *Kew Bull.* 24(1): 94 (1970).

Section *Austrocymbidium* Schltr. is here listed as a synonym of Sect. *Cymbidium* based on a sister relationships between *C. canaliculatum* and *C. aloifolium* (Zhang *et al.* 2019).

Cymbidium canaliculatum R.Br., *Prodr.* 331 (1810). *Type*: Queensland: Broad Sound, 25 Sept. 1803, *R.Brown* [*Bennett No. 5503*], (lecto: BM 000532695; isolecto: BM 000532696, BM 000532697, E 00686022, E 00686023, K 000891109, K 000891110), designated by M.A.Clements, *Austr. Orchid Res.* 1: 43 (1989).

Cymbidium hillii F.Muell. in Regel, *Gartenflora* 138–9 (1879); *Fragm.* 11: 88 (1880). *Type*: cult. Brisbane Botanic Gardens, ex in coastal forest Mulgrave Mountains, North Queensland, *W.Hill s.n.* (holo: ?MEL, *n.v.*).

Cymbidium sparksii Rendle, *J. Bot.* 36: 221 (1898); *Cymbidium canaliculatum* var. *sparksii* (Rendle) F.M.Bailey, *Compr. Cat. Queensl. Pl.* 845 (1913). *Type*: cult. London, 26 Apr. 1909, *J.Sparks* ex 'North-east Queensland', 20 April 1899, *A.O.Jones s.n.* (holo: BM 000532702; iso: K 000891108).

Cymbidium canaliculatum var. *canaliculatum* forma *inconstans* Rupp, *Proc. Linn. Soc. New S. Wales* 59: 98 (1934), *nom. illeg.*

Cymbidium canaliculatum var. *canaliculatum* forma *aureolum* Rupp, *Proc. Linn. Soc. New S. Wales* 59: 99 (1934). *Lectotype* (here designated): New South Wales: Pilliga, Oct. 1932, *H.M.R.Rupp s.n.* [Herbarium of Australian Orchids No. 387d] (lecto: NSW 596402; isolecto: NSW 596403).

Cymbidium canaliculatum var. *marginatum* Rupp, *Proc. Linn. Soc. New S. Wales* 59: 99 (1934). *Lectotype* (here designated): Queensland: Cairns, Oct. 1933, *W.F.Tierney s.n.* [Herbarium of Australian Orchids No. 387f] (lecto: NSW 807352; isolecto: NSW 807345).

Cymbidium canaliculatum var. *marginatum* forma *fuscum* Rupp, *Proc. Linn. Soc. New S. Wales* 59: 99 (1934). *Lectotype* (here designated): Queensland: Cairns, Oct. 1933, *W.F.Tierney s.n.* [Herbarium of Australian Orchids No. 387f] (lecto: NSW 807352; isolecto: NSW 807345).

?*Cymbidium canaliculatum* var. *marginatum* forma *purpurascens* Rupp, *Proc. Linn. Soc. New S. Wales* 59: 99 (1937). *Type*: Queensland: Proserpine, *C.Macpherson s.n.* (syn: ?NSW, *n.v.*); Head of Brisbane R., *F.A.Weinthal s.n.* (syn: ?MEL, *n.v.*).

Cymbidium canaliculatum var. *barrettii* Nicholls, *Austr. Orchid Rev.* 7: 40 (1942). *Type*: Northern Territory: Groote Eyland, Apr. 1940, *C.Barrett s.n.* (holo: MEL 0647418).

Illustrations: Hook.f., *Bot. Mag.* 96: t. 5851 (1870); Rupp, *Proc. Linn. Soc. New S. Wales* 59: 94–100, figs 1–3 (1934); Dockr., *Austr. Pl.* 3: 293–295, fig. (1966); Nicholls, *Orchids Austr.* 1: 630–632, t. 447 (1969); Brennan, *Wildfl. Kakadu* 59, pl. 98 (1986); M.Clark & S.Traynor, *Pl. Trop. Woodl.* 44, fig. (1987); D.L.Jones, *Native Orchids Austr.* 594, fig. (1988); J.Brock, *Top End Native Pl.* 133, pl. (1988); Du Puy & Cribb, *Genus* Cymbidium 90, pl. 8, 66–67, fig. 21.1 (1988); Dockr., *Austr. Indig. Orchids* (edn. 2); 2: 854, fig. p. 855 (1992); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1006, fig. 302a (1992); P.H.Weston in G.J.Harden, *Fl. New S. Wales* 4: 240, fig., pl. 17 (1993); Kenneally *et al.*, *Broome & Beyond* 213, pl. (1996); J.Puruntatameri *et al.*, *Tiwi Pl. & Animals* 41, pl. (2001); P.Wiynjorrotj *et al.*, *Jawoyn Pl. & Animals* 51, pl. (2005); D.L.Jones, *Compl. Guide Austr. Orchids* 466, pls. (2006); R.Melzer & J.Plumb, *Pl. Capricornia* 495, pl. (2007); A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 352, 364, 367 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 470, 475, 482, 483 (2013); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 746 pls (2021).

Robust erect *epiphyte* with crowded stems, pseudobulbs ellipsoidal to obovoid, 30–90 mm long, 15–30 mm wide, with 3–4 large bracts at the base, bracts up to 7 cm long. *Leaves* 3–7 per pseudobulb, distichous, largest at the top of the stem, alternate, dull green, linear to narrowly ovate, tapering to an acute apex, coriaceous and stiff, canaliculate, 80–400 mm long, 10–30 mm wide, disarticulating, 10–30 mm above the base. *Inflorescences* 1–3 per stem, erect to pendulous, arching, usually from the axils of the upper cataphylls, 200–400 mm long; peduncle 100–200 mm long, with 5–8 distant sheaths up to 3.5 cm long; rachis 60–250 mm long, with 15–50+ flowers, bracts 2–4 mm long, triangular, acute to acuminate. *Flowers* 25–50 mm wide, fragrant, usually widely spreading, light green or brown, purple or dull red, usually with lighter coloured margins or markings, labellum usually white with red or purple markings, callus ridges cream to pale green; pedicels 15–30 mm long. *Perianth*: sepals more or less oblong, 16–20 mm long, 4.5–6 mm wide, acute; petals narrowly elliptic, acute, 14–17 mm long, 4.5–5.5 mm wide; labellum 12–17 mm long, 4–7 mm wide when flattened, 3-lobed; lateral lobes crescent-shaped, erect, 1–2.5 mm long, 4–10 mm wide, midlobe usually decurved, 6–15 mm long, 5–10 mm wide; callus of 2, parallel, well-defined, ridges extending to midlobe, slightly hairy to papillose, the hairs extending onto the midlobe. *Column* yellowish-green or green, often blotched with red-brown, paler at the base, anther-cap cream or green to dark red-brown, 6–10 mm long, slightly curved, mottled, winged at apex; pollinia 2, about 1 mm long. *Anther* 1–1.5 mm across, rostrum indistinct. *Capsule* 40–50 mm long, 10–20 mm wide, ribbed, fusiform-ellipsoidal, shortly pedicellate, column persistent. (Figure 7).

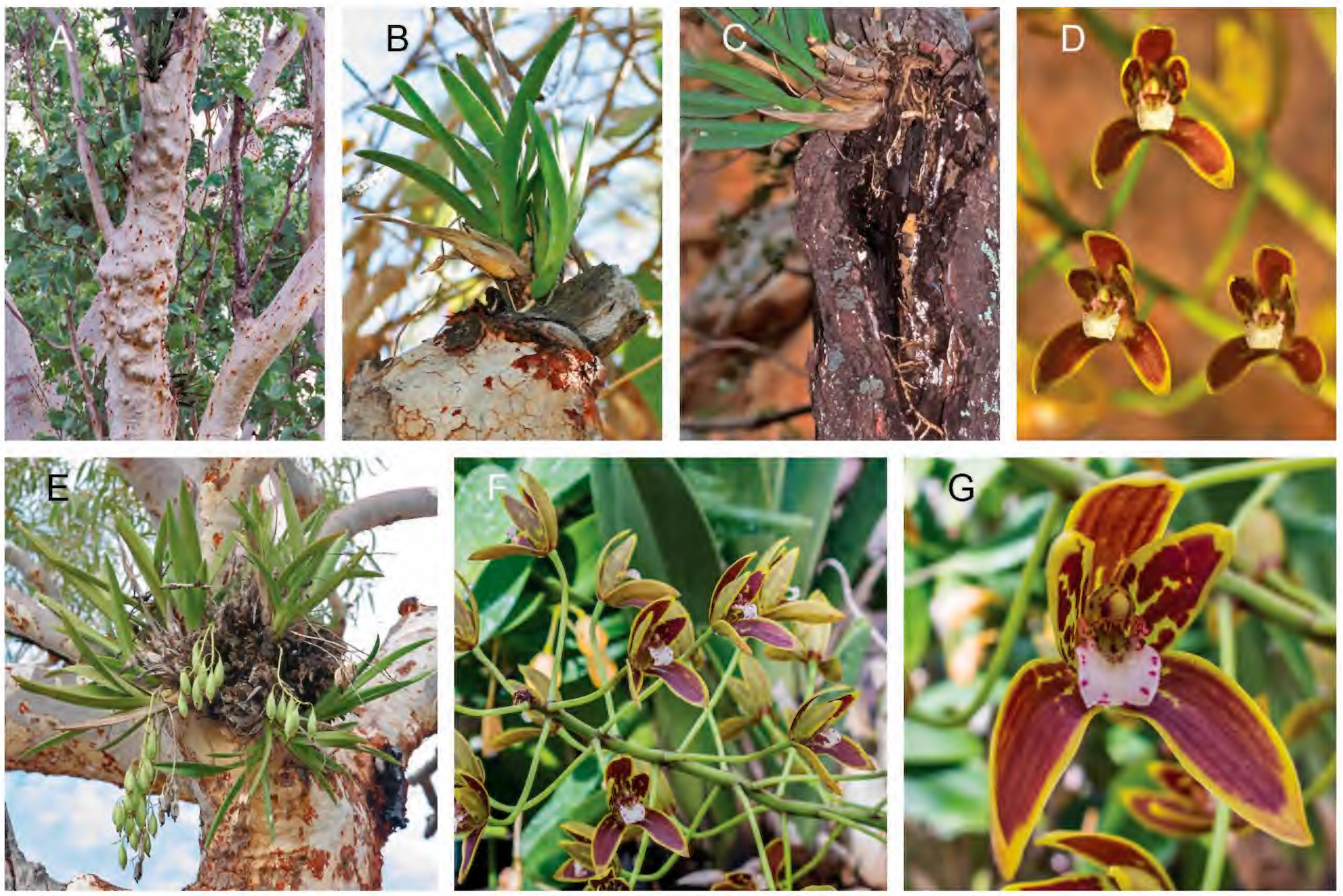

Fig. 7. *Cymbidium canaliculatum*. A–C. Habit and habitat in broken branches of living eucalypts. D. Flowers. E. Fruiting plant. F. Inflorescence. G. Flower. Vouchers: A: not vouchered, from SE of Mt Bomford; B, E: not vouchered, from Ragged Range, SW of Lake Argyle; C, not vouchered, from S side of Mt Bomford; F, G: not vouchered, cultivated at Kings Park & Botanic Garden from S side of Mt Bomford. Photos by R.L. Barrett.

Selected specimens examined: WESTERN AUSTRALIA: Beverley Springs Stn Hstd, 22 Dec. 1991, *R.L.Barrett* 12 (PERTH); Karrakatta Bay, 8 km NW of One Arm Point, N Dampierland, 07 Nov. 1987, *B.J.Carter* 141 (PERTH); Steep Head Island, Admiralty Gulf, N. Kimberley, 18 Nov. 1981, *T.P.Farrell* 976 (PERTH); Mount Herbert, near Inglis Gap, King Leopold Range, 17 May 1905, *W.V.Fitzgerald* 803 (PERTH); W5, Prince Regent River Reserve, 28 Aug. 1974, *K.F.Kenneally* 2170 (PERTH); adjacent to Granny's Soak campsite, edge Gardner Ra., N Tanami Desert, 10 May 1998, *K.F.Kenneally* 12036 (PERTH); Barker River, Sept. 1905, *J.Staer s.n.* (E 00686025*!); Roebuck Bay, Nov. 1891, *J.W.O.Tepper* 150 (PERTH); Roebuck Bay, 1892, *J.W.O.Tepper s.n.* (MEL). NORTHERN TERRITORY: Old Litchfield Road, 9 Sept. 1975, *C.R.Dunlop 3689* (CANB, DNA); Daily River settlement, 15 Jan. 1988, *N.M.Smith 1004* (DNA); Borroloola area, 12 Aug. 1991, *G.M.Wightman 5402* (DNA). QUEENSLAND: Maranoa, 28 miles [45 km] S of Roma on road to Surat, 29 Nov. 1972, *D.F.Blaxell 1049 & L.A.S.Johnson* (NSW); Cook, 19.4 km from Peninsula Development Road to New Dixie Station, 15 Oct. 1980, *J.R.Clarkson 3582* (NSW); NW of Goondiwindi, 1960, *L.Pedley 705* (CANB). NEW SOUTH WALES: 9.8 km N of the Rocky Dam - Wallangra road junction on road to Yetman, 2 Nov. 1983, *R.G.Coveny 11728 & P.G.Wilson* (NSW); cultivated at RBG Sydney [ex Mount Kaputar National Park, Waa Gorge, just upstream from twin pools], 20 Oct. 1987, *K.D.Hill 2775, L.A.S.Johnson & P.H.Weston* (NSW); Mole River, near Darby Creek, *c.* 6.9 km along Mole Station Rd, 9 Nov. 2018, *G.M.Taseski 923 & J.M.Cohen* (NSW).

Distribution: Widespread in the Kimberley region, less common in the northern regions of the Northern Territory and Queensland, but common and widespread in parts of southern Queensland and inland Northern New South Wales as far south as the Hunter River valley.

Conservation status: Widespread and not considered threatened (Du Puy and Cribb 1988, 2007) although an attractive apple-green variety is uncommon and eagerly sought after by collectors. This species may be subject to localised extinction along popular tourist routes where plants are souvenired by passing motorists.

Ecology: Epiphyte on a variety of hosts, mainly eucalypts, but also *Celtis*, *Melaleuca*, *Mimusops* and *Sterculia*. This species establishes on the rotting heartwood and bark of trees and in hollow branches, the roots growing down through the hollowed trunk of the tree and may even reach the ground and thus persist in dead trees and stumps.

Phenology: Flowers May–November, fruits June–December.

Affinities: On the basis of comparative morphological evidence considered to be most closely related to *C. hartinahianum* Comber & Nasution from northern Sumatra, *C. chloranthum* Lindl., from Sumatra, Java, Malaysia, Borneo and Palawan in the Philippines, and possibly *C. elongatum* J.J.Wood, Du Puy & P.S.Shim from Borneo (Du Puy and Cribb 1988). However, in a recent morphological and molecular based study (Zhang *et al.* 2019) revealed that *C. canaliculatum* was deeply embedded in subgenus *Cymbidium*, sister to the type species *C. aloifolium*, which is widespread throughout tropical SE Asia.

Typification: Rupp (1934) does not cite a type for his *Cymbidium canaliculatum* var. *canaliculatum* forma *inconstans* Rupp, but explicitly equates it with the type form of *Cymbidium canaliculatum* R.Br., so the name is illegitimate as he should have named it 'forma *canaliculatum*' (Art. 26.1, Shenzhen Code).

Two sheets of *Cymbidium canaliculatum* var. *canaliculatum* forma *aureolum* Rupp are held at NSW (NSW 596402 and NSW 596403). It is likely that both were originally mounted together, and were separated relatively recently, but this cannot be conclusively demonstrated, so we here designate the larger sheet (NSW 596402) as the lectotype of the name.

We identify two sheets at NSW with *Cymbidium canaliculatum* var. *marginatum* Rupp (NSW 807352 and NSW 807345). It is likely that both were originally mounted together, and were separated relatively recently, but this cannot be conclusively demonstrated, so we here designate the sheet with the original Rupp herbarium label (NSW 807352) as the lectotype of the name.

Rupp (1934) recognised two forms of his var. *marginatum*, but did not specify which was the typical form (which should have been called 'forma *marginatum*'). We here choose a lectotype for *Cymbidium canaliculatum* var. *marginatum* forma *fuscum* Rupp to equate it with that variety.

We have not chosen a lectotype for *Cymbidium canaliculatum* var. *marginatum* forma *purpurascens* Rupp as original material has so far not been located. We have also not located original material of *Cymbidium hillii* F.Muell.

Notes: There are two colour forms recorded for the Kimberley Region. The common form is mottled purple, brown and yellow-green. A rare lime-green form has been observed near Mount Elizabeth Station, King Edward River Crossing and on the Dampier Peninsula. The latter form has been described as *C. canaliculatum* var. *barrettii* Nicholls (1942) based on specimens from Groote Eylandt. This is probably a partially albino form. In some cases, the colour forms found in *Cymbidium canaliculatum s. lat.* are found in specific geographic areas. The deep red flowers of *C. canaliculatum* var. *sparksii* (Rendle) F.M.Bailey also correspond to inflorescences that are much more floriferous than other forms. Detailed discussions are provided by Rupp (1934) and Du Puy and Cribb (1988). While recent authors decline to recognise any of the named varieties, further investigation of variation in this species is warranted and is the subject of a current investigation by L. Simpson using molecular techniques.

Common names: Channel-leaf Cymbidium, Black orchid.

Dendrobium Sw., *Nov. Acta Reg. Soc. Sci. Upsal.*, ser. 2, 6: 82 (1799), *nom. cons. Type species*: *D. moniliforme* (L.) Sw., *type cons.*, designated by Pfeiffer, *Nomencl. Bot.*, 1(2): 1030 (1872); and see Holttum *et al.* (1979).

Notes: Delimitation of monophyletic genera within the Dendrobiinae remains in a state of flux at present with alternate classifications providing disparate concepts of how to best treat these orchids (Yukawa *et al.* 2000; Clements & Jones 2002; Clements 2003, 2006; Burke *et al.* 2008; Adams 2011; Pridgeon *et al.* 2014; Jones 2021). Publication of detailed molecular phylogenetic analyses of Dendrobiinae is pending (Nargar, Clements *et al.* in prep.), which will lend significant support to a revised classification. Since the latest results have yet to be published, for the sake of simplicity, a broad generic concept of *Dendrobium* is applied here pending improved resolution of relationships and corresponding taxonomic proposals.

Subgen. **Dendrobium**

Section **Phalaenanthe** Schltr., *Repert. Spec. Nov. Regni Veg. Beih.* 1: 447 (1912). *Type species*: *D. bigibbum* Lindl.

Dendrobium subg. *Pedilonum* sect. *Ceratobium* subsect. *Platypetala* Kraenzl. in Engl., *Pflanzenr.* IV. 50. II. B., 21: 139 (1910). *Type species*: *D. affine* (Decne.) Steud.

Vappodes M.A.Clem. & D.L. Jones, *The Orchadian* 13(11): 492 (2002). *Type species*: *Dendrobium bigibbum* Lindl.

Dendrobium dicuphum F.Muell., *Fragm.* 8: 28 (1873); *Callista dicupha* (F.Muell.) Kuntze, *Gen. Pl.* 2: 654 (1891); *Vappodes dicupha* (F.Muell.) M.A.Clem. & D.L.Jones, *The Orchadian* 13: 492 (2002); *Dendrobium bigibbum sensu* F.Muell., *Fragm.* 6: 119 (1868), *non* Lindl. (1853). *Type*: Northern Territory: Liverpool R., *B.Gulliver s.n.* (holo: MEL 624053; iso: K, MEL 624079, W).

Dendrobium dicuphum var. *grandiflorum* Rupp & T.E.Hunt, *Proc. Linn. Soc. New S. Wales* 72: 241 (1948). *Type*: Northern Territory: near Darwin, 1945, *G.L.Piper* or *R.J.Langdon 318* (lecto: BRI AQ0279506), designated by M.A.Clements, *Austr. Orchid Res*. 1: 46 (1989).

Dendrobium dicuphum var. *album* Hort. ex E.C.Cooper, *Roy. Hort. Soc. Dist. Gard*. 2: 653 (1951), *nom. illeg.*

Dendrobium affine auct. non (Decne.) Steudel: D.L.Jones, *Native Orchids Austral.* 432 (1988); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimberley Region* 1007 (1992); Dockr., *Austral. Indig. Orchids* (edn. 2); 2: 596 (1992).

Illustrations: Nicholls, *Orchids Austral.* 112, t. 415 (1969); N.Lothian, *Austral. Orchids* 47, pl. 49 (1981); Brennan, *Wildfl. Kakadu* 100, pl. 182 (1986); D.L.Jones, *Native Orchids Austral.* 432, fig. (1988), as *D. affine*; J.Brock, *Top End Native Plants* 135, pl. (1988), as *D. affine*; W.Upton, Dendrobium *Orchids Austral.* 19 fig. 10, pl. 7 (1989), as *D. affine*; A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimberley Region* 1007, fig. 302b (1992), as *D. affine*; Dockr., *Austral. Indig. Orchids* (edn. 2); 2: 596, fig. p. 597 (1992), as *D. affine*; Lavarack *et al.*, Dendrobium *and its relatives* 242, pl. (2000), as *D. affine*; P.Wiynjorrotj *et al.*, *Jawoyn Pl. & Animals* 54, pl. (2005), as *D. affine*; D.L.Jones, *Compl. Guide Austral. Orchids* 417, pl. (2006), as *Vappodes dicupha*; A.P.Brown *et al.*, *Orchids West. Austral.*, pls p. 368, 371 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austral.*, pls p. 471, 475, 484, 485 (2013); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 675 pl. (2021), as '*Durabaculum dicuphum*'.

Erect *epiphytic* herb; stems with pseudobulbs 50–350 mm long, *c.* 10 mm wide, slender fusiform. *Leaves* 3–10 at distal end of stem, erect to recurved, linear to narrowly ovate, 60–200 mm long, 10–25 mm wide, coriaceous, base sheathing, disarticulated and deciduous above the sheaths, acuminate. *Inflorescences* 1–4, semi-erect or recurved, 150–400 mm long with (2–)6–10(–20) flowers. *Flowers* spreading, white or cream, sometimes maroon, pink or green on lower part of labellum, 20–50 mm across; pedicels 10–20 mm long. *Dorsal sepal* oblong or narrowly ovate, shortly acute, 10–20 mm long, 4–7 mm wide. *Lateral sepals* narrowly ovate, 14–22 mm long, mentum up to 7 mm long. *Petals* obovate, 14–22 mm long, 5–8 mm wide. *Labellum* 3-lobed, 13–20 mm long, 7–13 mm wide when flattened; lateral lobes obliquely triangular, erect, enclosing the column, 3–5 mm long, 5–8 mm wide; midlobe oblong, 7–11 mm long, 2.5–5 mm wide, mucronate, keels 5, sometimes extending more than halfway along the midlobe, with calli or crested on the distal half. *Column* 3–4 mm long, 3–4 mm wide; foot, which is almost all spur, almost parallel to the body of the column, 4–6 mm long. *Anther c.* 2 mm in diameter; rostrum deflexed or decurved, broadly crescent shaped. *Rostellum* very short, transverse linear or crescentic. *Stigma* shield-shaped. Pollinia subequal, compressed slender falcate-obovoid. *Capsule* up to 20 mm long, 10 mm wide, glabrous, ribbed. (Figure 8)

Selected specimens examined: WESTERN AUSTRALIA: Crusher Vine Thicket, 6 km S of Mitchell Plateau mine camp, 05 June 1987, *J.J.Alford 525* (PERTH); Fiona Elizabeth Falls, Synnot Creek, 35 km NW of Beverley Springs Stn Hstd, 28 May 1995, *R.L.Barrett s.n.* (PERTH); Grevillea Gorge, from below Grevillea Pool to Synnot Creek, Synnot Range, Beverley Springs Station, 9 June 1995, *R.L.Barrett RLB 8639* (PERTH); Source of Calder River, Kimberley, 20 June 1922, *C.A.Gardner 893* [*1393*] (AD, NSW, PERTH); Mount Trafalgar, Prince Regent River Reserve, 26 Aug. 1974, *A.S.George 12705* (PERTH); Site 1, 13.5 km NE of Crystal Head, SW Osborne Island, Gardner Botanical district, 0.1 km to coast, 11 June 1987, *K.F.Kenneally* & *B.P.M.Hyland KFK 10336* (PERTH). NORTHERN TERRITORY: Melville Island, Jump-up Jungle, 1 Feb. 1984, *D.L.Jones 1338* (DNA); Elcho Island, Warangaiyu Lagoon, 4 July 1975, *P.Latz 6093* (DNA); Galiwinku community, Elcho Island, 29 Apr. 1987, *N.M.Smith 598* (DNA).

Distribution: From the Synnot Range and Walcott Inlet, north to the Mitchell Plateau and Bonaparte Archipelago in the north Kimberley. Also widespread in the 'top end' of the Northern Territory, disjunct from the Kimberley distribution.

Conservation status: Relatively widespread within its range and not considered threatened.

Ecology: Epiphytic on a variety of hosts, particularly *Lophostemon grandiflorus* subsp. *riparius* and *Sersalisia sericea*, but also *Eucalyptus*, *Pandanus aquaticus*, and in the Northern Territory, *Cycas*.

Phenology: Flowers May–August, fruits June–December.

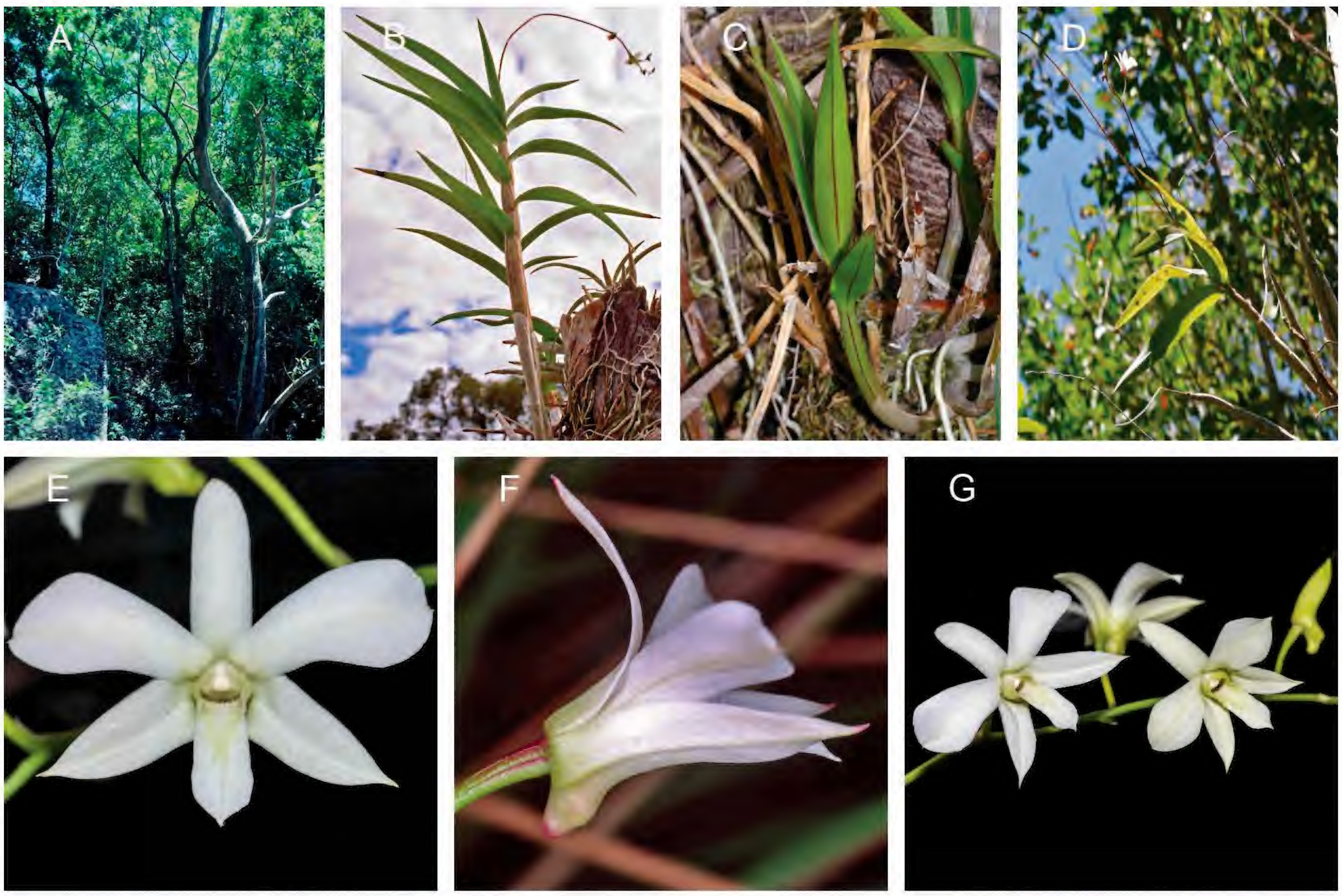

Fig. 8. *Dendrobium dicuphum*. A. Habitat. B–D. Habit. E–H. Flowers. I, J. Close-up of labellum. K. Fruit. Vouchers: A: not vouchered, from below Mount Daglish. B, C, E–J: not vouchered, cultivated at Kings Park & Botanic Garden from Grevillea Gorge, Synnot Range. D, K: not vouchered, from SW Osborne Island. Photos by R.L. Barrett & M.D. Barrett.

Affinities: Related to *D. affine*, a species from Timor, Flores (East Nusa Tenggara), Komodo and West Nusa Tenggara and adjacent small islands. *Dendrobium dicuphum* has often been considered a synonym of *D. affine* in recent decades (e.g. Wheeler 1992; Lavarack *et al.* 2000), however we consider *D. affine* a distinct taxon with longer inflorescences with numerous flowers; flowers with broader lateral petals; narrow side lobes clasping the column, an elongate-rectangular labellum midlobe with acute apex; predominantly white to cream coloured flowers often with a light green column, labellum side lobes and base of petals and sepals, and 3 rows of yellow, green or pink calli; all features not found in *D. dicuphum*. Lavarack *et al.* (2000) also noted the commonly shorter pseudobulbs in north-western Australian populations (as *D. affine*), though this character is variable in *D. dicuphum*.

Notes: Kenneally *et al.* (1991) recorded a *Bulbophyllum* sp. (*K.F. Kenneally* 10453) from rainforest on Neville Creek in the Harding Range. A visit to the site found only protocorms and adult plants of *D. dicuphum*. The material collected by Kenneally subsequently flowered in Canberra and was proven to be *D. dicuphum* (D.L. Jones pers. comm.), but was not vouchered.

Labellum colouration is variable on a seasonal basis. Interestingly, several populations in the vicinity of Beverly Springs (Charnley River) Station were observed to be all lime green one season, and all dark pink the following season (including a plant from the Edkins Range cultivated at Beverley Springs Station Homestead).

Common name: White butterfly orchid.

Dendrobium foelschei F.Muell., *S. Sci. Rec.* 2: 230 (1882); *Dendrobium canaliculatum* var. *foelschei* (F.Muell.) Rupp & Hunt, *Proc. Linn. Soc. New S. Wales* 72: 240 (1948); *Callista foelschei* (F.Muell.) Kuntze, *Revis Gen. Pl.* 2: 654 (1891); *Cepobaculum foelschei* (F.Muell.) M.A.Clem. & D.L.Jones, *The Orchadian* 13: 486 (2002); D.L.Jones, *Compl. Guide Austr. Orchids* 381, pl. (2006). *Type*: Northern Territory: Near Port Darwin; Sept. 1882, *P.Foelsche* (holo: MEL 93793; iso: AD 96945320, K 001085448, MEL 93794, W (Reichenbach Herb. Orchid. No. 40224)).

Illustration: D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 672 pl. (2021), as '*Durabaculum foelschei* (ined.)'.

Erect *epiphytic* herb; stems in small tufts, pseudobulbous *c.* 20–80 mm long, 5–10 mm wide, slender fusiform, those newly formed covered in sheathing bracts that gradually disintegrate as they get older exposing shallowly sulcate bare surface. *Leaves* 2–6, canaliculate, carnose, semi-cylindrical or tapered slightly from the base to the apex, acute or acuminate, lamina 40–170 long, 3–6 mm wide. *Inflorescence* of 1–6 racemes arising from terminal and subterminal nodes, *c.* 80–300 mm long, axis 1–2 mm wide, the peduncle equal to or shorter than the rachis; rachis bearing from 2–20 flowers; pedicels 10–25 mm long, 0.3–0.5 mm wide. *Flowers* 12–35 mm across, patent, porrect, often not opening widely, fragrant, tepals generally twisted to a variable extent, white, cream in the basal half, pale yellow or pale brown in apical half; labellum white or cream, pale yellow or green in basal half, rich pink-purple in apical half. *Dorsal sepal* 9–17 mm long, 1.5–2.5 mm wide, oblong-linear, acute, slightly broader in basal half. *Lateral sepals* similar to dorsal sepal in size and length but also obliquely falcate. *Petals* spreading, slightly longer than the dorsal sepal, 13–23 mm long, 2–2.5 mm wide, narrowly oblong-spatulate with an acute almost obtuse apex. *Labellum* stiffly attached to the apex of the column foot, markedly dissimilar in size and shape to the sepals and petals, calcarate, lamina narrowly triangular, fleshy, strongly trilobed; lateral lobes prominent, obliquely triangular, erect, entire with obtuse apices, incurved embracing the column; midlobe porrect or slightly decurved, narrowly to broadly rhombic or elliptical with distinct narrow base and apiculate or acuminate apex, 9–13 mm long, 4.5–6 mm wide when flattened; calli consisting of 3 narrow parallel ridges, extending along the midlobe for about three-quarters of its length, becoming enlarged, prominent, lamellate, crested and irregular on the midlobe. *Column* 3–4 mm long, fleshy, nearly straight, with highly reduced ventral tooth-like apical stelidia. *Column* foot well developed, similar in length to column, straight or slightly curved, 3–4 mm long, narrowing towards base. *Stigma* entire ovate, concave. *Rostellum* ventral, swollen transverse. *Anther* terminal, incumbent, 2-celled, persistent, attached dorsally by a ligulate claw, smooth, erostrate or with a short rostrum, apex papillate. *Pollinia* 4 in 2 subequal, pairs, obovoid to falcate, yellow, hard waxy.

Selected specimens examined: NORTHERN TERRITORY: Magela Creek, near Island Billabong, 12 Feb. 1984, *I.D.Cowie 181* (DNA); Melville Island; 15 km S of Snake Bay, 31 Jan. 1984, *D.L.Jones 1334* (DNA); Arnhem Land, 8km NE of Maningrida, 17 June 1987, *G.M.Wightman 3863* (DNA). QUEENSLAND: cultivated [ex 4 km S of Elliot Falls], 15 Oct. 1996, *E.Lielkajis ORG327* (CANB).

Distribution: Scattered across the top-end of the northern Territory and disjunct populations near the tip of Cape York in far north Queensland. The single historical population recorded from Western Australia is no longer extant.

Conservation status: Relatively widespread within its range and not considered threatened.

Ecology: Epiphytic on a variety of hosts, particularly *Melaleuca* species and *Barringtonia acutangula*.

Phenology: Flowers July to September.

Affinities: Similar to *D. canaliculatum* R.Br. but the leaf-bearing axes not as swollen and the axes are generally longer in *D. foelschei*; leaves are very slender, almost terete; sepals are slightly narrower and more sharply acute than those of *D. canaliculatum*; petals narrowly oblong-spatulate with a distinctly apiculate or acuminate midlobe with a narrow base.

Notes: *Dendrobium foelschei* has been reported to occur in the north Kimberley region based on living material collected by the late W.H. Butler and cultivated in a glasshouse at the Western Australian Herbarium by A.P. Brown who confirmed the identification when the plant flowered. Unfortunately, no voucher is known to have been made before the plant died, and there are no other records for Western Australia. It seems reasonable to accept the origin of the plant as both A.P. Brown and K.W. Dixon discussed this directly with W.H. Butler and the site was subsequently visited and found to be consistent with verbal descriptions, but a hot fire had recently scorched all canopies in the area and no trace of the species could be found (K.W. Dixon pers. comm.). This record was referred to as *D. canaliculatum* in Wilson (1992). It is not known whether the species still persists in the Kimberley.

Common name: Thin tea tree orchid.

Dendrobium species

Gardner (1923) noted a purple flowered *Dendrobium* sp. observed on *Eucalyptus houseana* in the vicinity of the Prince Regent River. However, no collections were made and the identity remains unknown. The flowers were described as being large and conspicuous. Gardner considered the plant he saw to be distinct from *D. dicuphum* and from *Cymbidium canaliculatum*, which were observed on the same expedition in 1919.

Didymoplexis Griff., *Calcutta J. Nat. Hist*. 4: 383, t. 17 (1843). *Type*: *D. pallens* Griff.

Notes: *Didymoplexis* has been considered to be a fairly small genus of about ten species (Hemsley 1884; Lavarack 1977; Hsu & Chung 2007; Cribb *et al*. 2013; Zhou *et al*. 2016; Gray 2017), but additional taxa have come to light in recent years and it is likely that more will be discovered as they are easily overlooked (Ormerod 2000; Cribb *et al*. 2013; Suddee 2014; Suetsugu *et al*. 2017; Suetsugu & Hsu 2019). It has also been suggested that the circumscription should include *Didymoplexiella* Garay (see Averyanov 2010; Suetsugu & Hsu 2019).

Didymoplexis pallens Griff., *Calcutta J. Nat. Hist*. 4: 383, t. 17 (1843); *Epiphanes pallens* (Griff.) Rchb.f. in Seeman, *Fl. Vit*. 296 (1868); *Gastrodia pallens* (Griff.) F.Muell., *Contr. Phytogr. New Hebrides* 22 (1870). *Type*: India: near bamboo clumps, Serampor, Calcutta, *W.Griffith s.n.* (type: CAL, *n.v*. (possibly lost); icon t. 17).

Leucorchis sylvatica Blume, *Mus. Bot*. 1: 31 (1849); *Didymoplexis sylvatica* (Blume) Ridl., *J. Bot*. 345 (1884). *Type*: Indonesia: Bantam Province, Island of Java, Harriang, *T.Horsfield s.n*. (holo: *n.v*.; iso: BM 000061576).

Apetalum minutum Wight, *Icon. Pl. Ind. Or*. 5: 22, t. 1758 (1851). *Type*: India: Near Sultan's Battery in Coorg, under a clump of Bamboos, *T.Jerdon ex R.Wight s.n.* (holo: K; iso: K).

Arethusa ecristata Griff. in McClell., *Not. Pl. Asia* 5(3): 378-379 (1851). *Type*: (icon t. 343, *Icon. Pl. Asia*. (1847). *Note*: Major components of this plate are taken from Griffith's earlier published illustration of *D. pallens*.

?*Pogonia pachystomoides* F.Muell., *Fragm*. 8: 174 (1874); *Nervilia pachystomoides* (F.Muell.) Schltr., *Bot. Jahrb. Syst*. 45: 404 (1911); *Didymoplexis pachystomoides* (F.Muell.) Garay & W.Kittr., *Bot. Mus. Leafl*. 30(3): 48, 182 (1986). *Type*: Queensland: Ad sinum Rockingham's Bay, *W.Hill* 307 (holo: MEL 677521!).

Arethusa bengalensis Hort. ex Hemsley, *J. Proc. Linn. Soc. Bot*. 20: 311 (1884), *pro syn*.

Cheirostylis kanarensis Blatter & McCann, *J. Bombay Nat. Hist. Soc*. 35: 732–733, fig. 4 (1932). *Type*: Bombay: N. Kanara: Tatwal, June 1912, *T.R.Bell s.n*. (holo: *n.v*.).

Illustrations: Hemsley, *J. Proc. Linn. Soc. Bot*. 20: 308, pl. 28 (1884); King & Pantl., *Ann. Roy. Bot. Gard*. (*Calcutta*) 8: 260, pl. 364 (1898); J.J.Sm., *Orchid Java Fig. Atlas* 1 fig. 51 (1908); Lavarack, *Austrobaileya* 1(1): 63 fig. 2a (1977); Lavarack, *The Orchadian* 5(11): 159, fig. 1 (1978); Lavarack & B.Gray, *Trop. Orchids Austral*. 96, pl. 51 (1985); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimberley Region* 1008, fig. 303c (1992); Dockr., *Austral. Indig. Orchids* 1 (edn. 2): 255, pl. p. 256 (1992); D.L.Jones, *Compl. Guide Austral. Orchids* 368, fig., pl. (2006); A.P.Brown *et al*., *Orchids West. Austral*., pls p. 372, 375 (2008); A.P.Brown *et al*., *Field Guide Orchids West. Austral*., pls p. 475, 486, 487 (2013); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 634, 635, pl., fig. (2021).

Leafless, achlorophyllous *mycoheterotroph*, 80–300 mm high at anthesis; stem white or reddish, with a few small, scarious bracts, arising from stem tubers up to 100 mm long. *Inflorescence* a raceme bearing 5–15 flowers. *Flowers* 7–14 mm long, glistening white with a yellow spot at the base of the labellum, short-lived, usually only 1 open at any time, erect; bracts triangular, *c*. 4 mm long; pedicels orange, up to 5 mm long at anthesis, elongating to 40–200 mm long in fruit. *Dorsal sepal c*. 10 mm long, adnate to the petals for *c*. half its length. *Lateral sepals* connate for *c*. half their length and adnate to the petals for a short distance, 6–7 mm long, obtuse. *Petals* 6–7 mm long, obtuse. *Labellum* variable in shape, usually 2-lobed and 4–7 mm long, *c*. 10 mm wide when flattened out, with a longitudinal row of calli almost the entire length of labellum and *c*. 2 mm wide. *Column* 4–6 mm long, curved, dilated laterally towards the apex to form broad wings which terminate as teeth below the anther, foot curved, 2–3 mm long. *Anther c*. 1.5 mm diameter; pollinia with a thick retinaculum. *Stigma* rectangular. *Capsule* orange, finely ribbed, 13–16 mm long, 3.6–4.3 mm wide. (Figure 9).

Specimens examined: WESTERN AUSTRALIA: Gwen's Gorge, off S arm of Bachsten Creek, Edkins Range, 6 Dec. 1994, *R.L.Barrett & M.D.Barrett RLB 948* (PERTH); Edkins Range, 62 km N of Beverley Springs Station Homestead, 26 Dec. 1995, *R.L.Barrett & M.D.Barrett RLB 633* (PERTH); *loc. cit*., 8 Jan. 2001, *R.L.Barrett & K.W.Dixon RLB 1644* (PERTH). NORTHERN TERRITORY: Douglas-Daly Experimental Farm, 5 Dec. 1988, *J.Russell-Smith 6489* (DNA); 19 km N of Mirrngadja, Arnhem Land, 5 Nov. 1987, *C.R.Dunlop & G.J.Leach 1551* (DNA). QUEENSLAND: W of Cairns, 2004, *B.Gray 8888* (CANB); Dauan Island, 1989, *D.L.Jones 3660* (CBG).

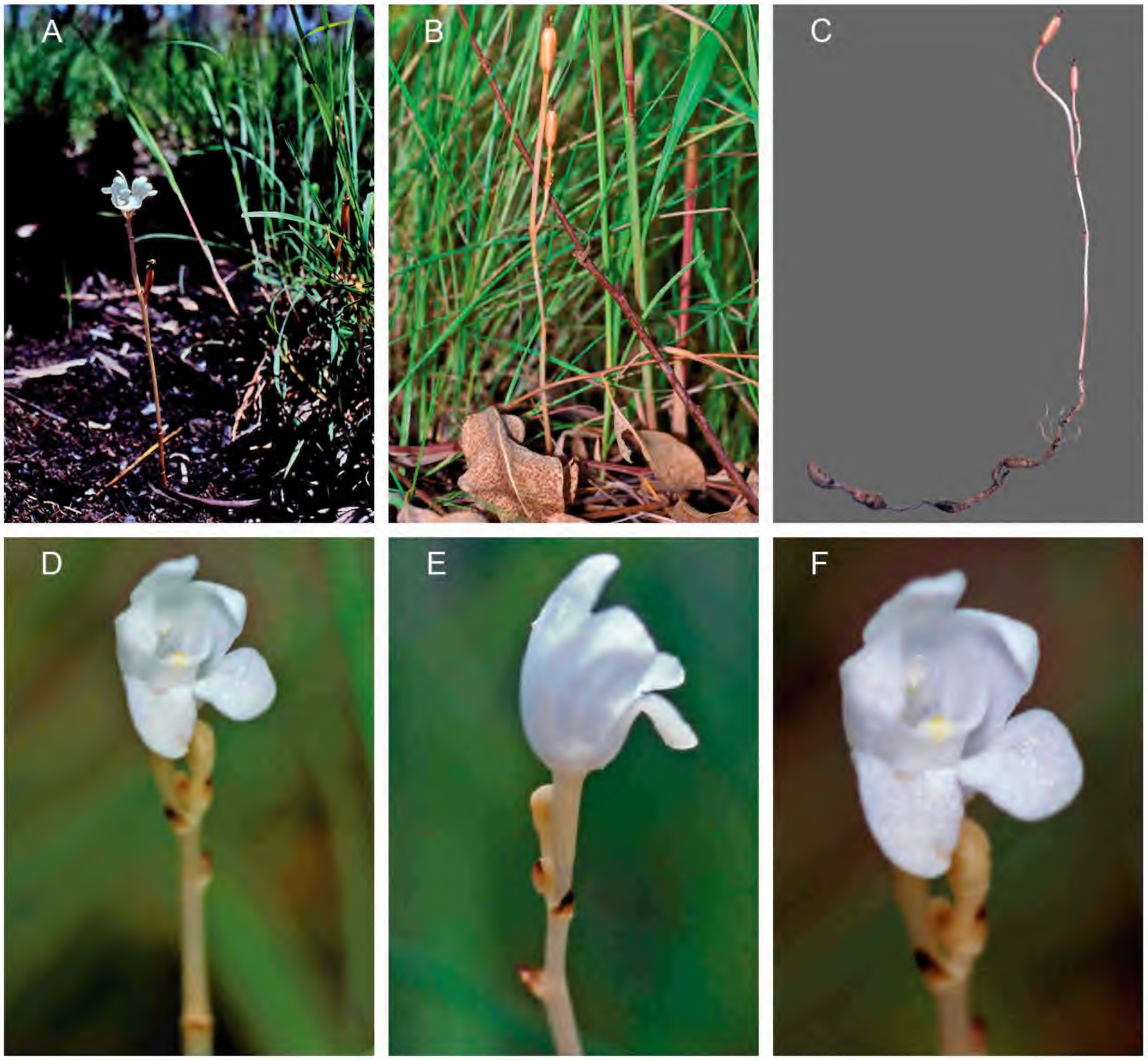

Fig. 9. *Didymoplexis pallens*. A. Flowering plant post-fire. B. Fruiting plant on edge of burnt area. C. Whole plant including root system. D–F. Flower. Voucher: *R.L.Barrett & K.W.Dixon RLB 1644* (PERTH). Photos by R.L. Barrett.

Distribution: Scattered in Australia, in the North Kimberley of Western Australia, the 'top end' of the Northern Territory and north Queensland. Widespread outside Australia, including Afghanistan, China, Japan, Taiwan, Assam, Bangladesh, India, Nepal, Myanmar, Thailand, Vietnam, Malaysia, Indonesia, Christmas Island, Papua New Guinea, Vanuatu and New Caledonia.

Conservation Status: This species is very restricted in its habitat in Western Australia, and is possibly under threat from frequent burning at all known locations, since fire is removing critical humus layers required for the survival of tuberoids over the dry season. Listed as Priority One for Western Australian flora (Florabase 1998 onwards). Listed as Data Deficient in the Northern Territory (Franklin & Kerrigan 2005; Woinarski *et al.* 2007).

Ecology: Occurs in dense closed grassland on peaty soils in association with *Banksia dentata*, *Byblis liniflora*, *Calochilus barbarossa*, *C. kimberleyensis, Clitoria australis*, *Empusa habenarina, Drosera paradoxa*, *Eucalyptus apodophylla*, *E. houseana*, *E. alba*, *Eulophia bicallosa*, *Haemodorum flaviflorum*, *Hypoxis nervosa, Lindernia plantaginea, Empusa habenarina*, *Ludwigia octovalvis*, *Melaleuca viridiflora*, *Pandanus spiralis* var. *spiralis, Pecteilis eurystoma*, *Stylidium pachyrrhizum, Utricularia uliginosa* and *Xyris complanata*.

Phenology: Flowers and fruits December–January.

Affinities: Only two species of *Didymoplexis* are known from Australia. *Didymoplexis micradenia* (Rchb.f.) Hemsl. differs in having pinkish-white flowers, a short column foot *c.* 1 mm long, and a finely toothed labellum apex (Gray 2017).

Notes: Hundreds of plants were observed in a single population following fire on one occasion. *Didymoplexis* is reliant on fungal species associated with Poaceae. It is not known whether fire stimulates mass-flowering or if this simply made the plants easier to locate. A return visit to the site three years post-fire found only a few plants, though this was toward the end of the flowering season. It is interesting to note that the Kimberley populations may be the only ones known that are not in direct association with a member of Poaceae subfam. Bambusioideae, growing instead with *Arundinella nepalensis*, *Germainia truncatiglumis* and *Mnesithea rottboellioides*, but any specific associations remain uncertain.

A number of new *Didymoplexis* taxa have been described from Asia in recent years (Averyanov *et al.* 2019; Suetsugu *et al.* 2017; Suetsugu 2019) and further research is required to confirm that the correct name is being applied to the material collected in northern Australia and the status of those species listed as synonyms are conspecific. Comparative study of the types and protologues listed above, including illustrations, suggests that more than one species is included under this concept.

Common names: Potato orchid, Crystal bells.

Dipodium R.Br., *Prodr.* 330 (1810). *Type*: *Dendrobium punctatum* Sm. (= *Dipodium punctatum* (Sm.) R.Br.).

Note: *Dipodium* is phylogenetically related to *Cymbidium*, and is of interest for containing both climbing leafy species and saprophytic species (O'Byrne 2014).

Dipodium ammolithum M.D.Barrett, R.L.Barrett & K.W.Dixon, *sp. nov.*

Type: Western Australia: Edkins Range, 76 km N of Beverley Springs Station Homestead, 16°02'S, 125°23'30"E, 28 December 1995, *R.L.Barrett* & *M.D.Barrett RLB 688* (holo: PERTH 08042101; iso: CANB, DNA, K).

Dipodium sp. Sandstone (R.L. Barrett & K.W. Dixon RLB 1642), Western Australian Herbarium. (1998–). FloraBase – The Western Australian Flora. Department of Environment and Conservation. http://florabase.dpaw.wa.gov.au/ [accessed 14 August 2012].

Illustrations: A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 376, 381 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 472, 475, 488, 489 (2013).

Terrestrial, erect, saprophytic, leafless *herb* with short subterranean *rhizome* covered with imbricate bracts, with an extensive system of thick carnose roots; branches of the rhizome covered with imbricate bracts and terminating in an inflorescence up to 140 cm tall, although generally 50–70 cm tall; *peduncle* longer than or about equal to the rachis, *c.* 3 mm diam. at base of inflorescence, 1.5–2 mm diam. at apex of inflorescence, mostly vinaceous, to pink, purplish brown or dark mauve, straw-coloured in patches, furnished with four to nine sheathing *bracts* 9–17 mm long; *rachis* often completely dark pinkish purple (not flecked or streaked), bearing 15–45 usually well-spread flowers; *floral bracts* small, shortly sheathing, 4.0–5.7 mm long, 0.9–1.2 mm wide; *pedicels* 13–15 mm long in flower, slender, twisted; *ovaries* 6.5–8.7 mm long, 0.7–1.1 mm wide, ribbed, purple, usually slightly curved. *Flowers* erect or pendant, 18–24 mm diam., patent, held at 15–45° to horizontal; *tepals* somewhat recurved, adaxially uniform pale pink with the only markings a slightly darker pink midline and veins, abaxially very faintly speckled. *Dorsal sepal* 12.5–16.4(–20.3) mm long, 1.0–2.5(–3.2) mm wide, *c.* narrowly oblong obovate, obtuse. *Lateral sepals* 11.1–18.2(–20.9) mm long, 1.6–2.6(–2.9) mm wide, narrowly oblong-elliptical to oblong obovate, obtuse, slightly falcate. *Petals* 13.1–18.0(–27.6) mm long, 1.4–1.8(–3.2) mm wide, narrow falcate-oblong, bluntly acute. *Labellum* porrect, slightly upcurved in the distal half, 3-lobed, 7.8–12.6 mm long, 3.1–4.5 mm wide, dark pink; lateral lobes pink, projected forwards, not out-curved when fresh, sometimes spreading when dry, equal to or slightly longer than column, 2.3–3.0 mm long, 0.7–0.8 mm wide, *c.* narrowly oblong, pubescent towards the base; midlobe 7.3–9.0 mm long, 2.6–3.1 mm wide, narrow rhomboid to narrow elliptical, more or less acute, furnished from about three quarters to the apex with a central band (for 3–4.5 mm), which is broadest at the distal end, of hairs which are more or less tangled, 0.4–0.6 mm long and purplish, minutely papillose (papillae *c.* 0.05 mm long) over most of length; *disc* furnished with two sublinear pubescent keels 5.3–8.0 mm long, 0.5–0.7 mm wide which generally diverge at the distal end. *Column* closely parallel to the labellum, 5.8–8.1 mm long, 1.6–2.4 mm wide, dilated in the distal half and narrowly winged at the apex, anterior surface below the middle furnished with a pink pubescent patch; apical margin of column sinuate or incised. *Stigma c.* 1.0 mm diam., depressed ovate to semicircular. *Anther* cap 1.8–2.1 mm long, 0.9–1.4 mm wide, rostrum decurved, large, apex projecting. *Pollinarium* 1.2–1.4 mm long; retinaculum *c.* 0.8 mm long, ovate; stipes *c.* 1.0 mm long; pollinia *c.* 0.6 mm long, obovoid, dark yellow. *Capsule* 14–16 mm long, 7–10 mm wide, prominently ribbed, sometimes cream, usually pale to dark pink or purple. (Figure 10)

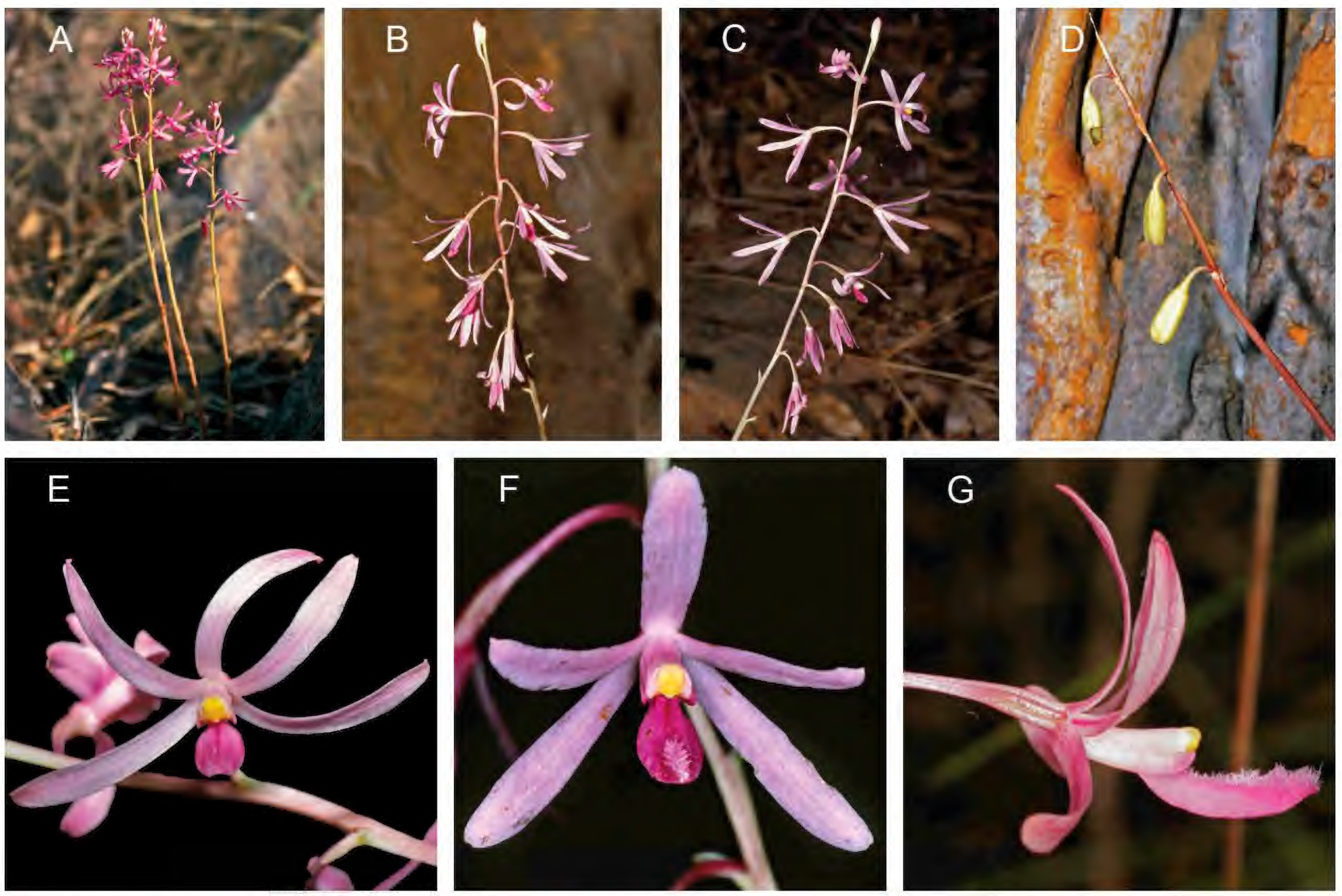

Fig. 10. *Dipodium ammolithum*. A. Habit. B, C. Inflorescence. D. Infructescence. E–G. Flower. H. Close-up of labellum from above. I. Close-up of column and labellum base. J. Fruit. Vouchers: A: *R.L.Barrett & M.O'Connor RLB 1572* (PERTH); B–E: *R.L.Barrett* & *M.D.Barrett RLB 1726* (PERTH); F: *M.D.Barrett 1371* (PERTH); G–J: *R.L.Barrett* & *M.D.Barrett RLB 3922* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Diagnostic characters: Similar to *D. basalticum* and *D. stenocheilum*, differing from both in lacking any tepal markings (except sometimes faintly pigmented veins), and habitat on broken sandstone.

Specimens examined: WESTERN AUSTRALIA: 2.6 km NW of Mt Hann, Mt Hann, near Prince Regent Reserve, 26 Jan. 2000, *M.D.Barrett 912* (PERTH); 6 km ENE of junction of Pitta Creek and Prince Regent River, 29 Jan. 2000, *M.D.Barrett 955* (PERTH); 10 km ESE of Mt Agnes near watershed of Drysdale and Prince Regent Rivers, NW Kimberley, 21 Jan. 2003, *M.D.Barrett 1371* (PERTH); Theda Station, 13 Jan. 2016, *M.D.Barrett MDB 4910* (PERTH); Edkins Ra., 81 km NNW of Beverley Springs Stn Hstd, 28 Dec. 1995, *R.L.Barrett* & *M.D.Barrett RLB 663* (PERTH); Edkins Ra., 76 km N of Beverley Springs Stn Hstd, 9 Jan. 1995, *R.L.Barrett* & *M.D.Barrett RLB 967* (PERTH); *c.* 8.5 km NE of Mount Agnes, 6 Jan. 2001, *R.L.Barrett & M.O'Connor RLB 1572* (PERTH); near prospecting camp, *c.* 2 km SW of Mount Fyfe, 6 Jan. 2001, *K.W.Dixon per R.L.Barrett 1642* (CANB, PERTH); 6.5 km NE of junction of Pitta Creek and Prince Regent River, W of Reserve boundary, 10 Jan. 2001, *R.L.Barrett 1719* (PERTH); 1 km S of Mount Fyfe, 11 Jan. 2001, *R.L.Barrett* & *M.D.Barrett RLB 1726* (PERTH); Theda Station, *c.* 3 km SE of homestead, on sandstone ridge behind rubbish dump, 23 Feb. 2006, *R.L.Barrett* & *M.D.Barrett RLB 3288* (PERTH); Large gully, 10.8 km NE of junction of Youwanjela Creek and Prince Regent River, Prince Regent Nature Reserve, 20 Jan. 2007, *R.L.Barrett* & *M.D.Barrett RLB*

3666 (PERTH); 'Shrimp Creek' (informal name), 11.7 km S of Kings Cascades, Prince Regent River Reserve, 22 Jan. 2007, *R.L.Barrett* & *M.D.Barrett RLB 3719* (PERTH); Gwens Gorge south arm, NE of Bachsten Creek Bush Camp, southern boundary of Prince Regent Nature Reserve, 24 Jan. 2007, *R.L.Barrett* & *M.D.Barrett RLB 3810* (PERTH); 'Acacia Flat' (informal name), Princess May Ranges, 21.6 km due N of Kings Cascades, Prince Regent Nature Reserve, 25 Jan. 2007, *R.L.Barrett* & *M.D.Barrett RLB 3922* (PERTH); 'Leptospermum falls' (informal name) pavement 2, E of Prince Regent Nature Reserve boundary, 16 Jan. 2010, *R.L.Barrett, M.D.Barrett & M.Maier RLB 6103* (PERTH); Sandstone pavement E of Mount Brookes, Prince Regent Nature Reserve, 19 Jan. 2010, *R.L.Barrett, M.Maier & P.Kendrick RLB 6265* (PERTH); side arm of Pitta Gorge, Prince Regent Nature Reserve, 23 Jan. 2010, *R.L.Barrett, P.Kendrick & G.Sparkes RLB 6358* (PERTH).

Distribution: Apparently endemic to the sandstone ranges of the north-west Kimberley, from the Edkins Range, north to Theda Station.

Etymology: From the Greek *ammo-* (sand) and *lithos* (stone) in reference to the particular habitat of this species.

Conservation status: This species is common within its limited range and is well represented in the Prince Regent National Park. It is not currently under threat.

Ecology: Occurs in deep leaf litter on sandstone scree or outcrops, often with *Brachychiton viscidulus*, *Ficus* spp., *Gardenia* spp., *Planchonella pohlmaniana* and *Planchonia rupestris* over *Triodia* spp. Occasionally in vine thicket over sandstone with *Blechnum indicum*, *Dioscorea bulbifera*, *Ficus brachypoda, F. racemosa*, *Pavetta kimberleyana*, *Strychnos lucida*, *Syzygium angophoroides, Xanthostemon paradoxus*. Direct sequencing of the Internal Transcribed Spacer (ITS) region from two central tissue samples of root tubers from a specimen of this species from Theda Station (*M.D. Barrett MDB 4910*, PERTH) returned two identical sequences of a *Lactifluus* (Pers.) Roussel (Russulaceae; GenBank record ON819578). This suggests that the primary endophytes of *Dipodium ammolithum* are Russulaceae, in agreement with previous findings (Bougoure & Dearnaley 2005; Dearnaley & Le Brocque 2006; Boddington *et al*. 2016). A third tuber tissue sample (GenBank ON819579) sequenced from this same *Dipodium* specimen belonged to the genus *Clitopilus* (Entolomataceae; e.g 97.4% BLAST match to *Clitopilus prunulus* EU273512). Species of *Clitopilus* are usually considered saprophytes, but *C. hobsonii* (Berk.) P.D.Orton has recently been recorded as a root symbiont of *Liquidambar* (Peng *et al*., 2021). The presence of *Clitopilus* in this *Dipodium* sample is most likely incidental, but the possibility of a symbiotic interaction cannot be excluded.

Phenology: Flowers and fruits December–January.

Common name: Sandstone hyacinth orchid.

Dipodium basalticum M.D.Barrett, R.L.Barrett & K.W.Dixon, *sp. nov*.

Type: Southern tributary of the Roe River, NNW of Mount Fyfe, Western Australia, 11 January 2001, *K.W.Dixon* per *R.L.Barrett RLB 1766* (holo: PERTH 08042136).

Dipodium stenocheilum auct. non O.Schwarz: D.L.Jones, *Native Orchids Austr.* 406 (1988), *p.p*. as to Kimberley; A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1008, fig. 303d (1992); Dockr., *Austr. Indig. Orchids* (edn. 2): 2: 834 (1992), *p.p*. as to Kimberley.

Dipodium sp. Basalt Woodland (M.D. Barrett 198), Western Australian Herbarium. (1998–). FloraBase – The Western Australian Flora. Department of Environment and Conservation. http://florabase.dpaw.wa.gov.au/ [accessed 14 August 2012].

Illustrations: A.P.Brown *et al*., *Orchids West. Austr.*, pl. p. 379 (2008); A.P.Brown *et al*., *Field Guide Orchids West. Austr.*, pls p. 489 (2013).

Terrestrial, erect, saprophytic, leafless *herb* with short subterranean *rhizome* covered with imbricate bracts, with an extensive system of thick carnose roots; branches of the rhizome covered with imbricate bracts and terminating in an inflorescence up to 120 cm, although generally 70–90 cm tall; *peduncle* longer than or about equal to the rachis, 6–8(–9.5) mm diam. at base of inflorescence, 0.8–1.2 mm diam. at apex of inflorescence, generally pale cream to purple, furnished with four to six sheathing *bracts* 1–2 cm long; *rachis* often suffused with pinkish purple, bearing 35–70 rather crowded flowers; *floral bracts* small, sheathing, 6–8.5 mm long, 1 mm wide; *pedicels* 12–16 mm long in flower, slender, twisted; *ovaries* 5.5–7.5 mm long, 1–1.5 mm wide, ribbed, cream, straight to slightly curved. *Flowers* erect (rarely slightly pendant), 24–30 mm diam., patent, usually held at 15–45° to horizontal; *tepals* somewhat recurved, adaxially generally pale pink to white, usually with some small flecks and stripes of a darker shade, abaxially darker pink with scattered flecks of a darker shade, more prominent at the distal end. *Dorsal sepal* 11.2–14.8 mm long, 2.2–3.2 mm wide, *c*. narrowly oblong obovate, bluntly acute. *Lateral sepals* 11–18 mm long, 2.3–3.0 mm wide, narrowly oblong-elliptical to oblong obovate,

bluntly acute, sometimes slightly falcate. *Petals* 12.2–15.8 mm long, 2.4–2.8 mm wide, narrow falcate-oblong, bluntly acute. *Labellum* porrect, slightly upcurved in the distal half, 3-lobed, 12.3–20.5 mm long, 2.9–5.7 mm wide, pale to dark pink; lateral lobes lighter in colour than the midlobe, projected forwards, not out-curved when fresh, often spreading when dry, equal to or slightly longer than column, 3.4–3.8 mm long, 0.7–0.8 mm wide, *c.* narrowly oblong, pubescent towards the base; midlobe 10–13 mm long, 2.4–3.0 mm wide, narrow rhomboid to narrow elliptical, more or less acute, furnished from about two thirds to the apex with a central band, which is broadest at the distal end, of hairs which are more or less tangled, 0.2–0.4 mm long and generally mauve, with another patch of dense hairs at the base of the lobes; *disc* furnished with two sublinear pubescent keels 5.2–8.6 mm long, 0.6–0.9 mm wide which generally diverge at the distal end. *Column* closely parallel to the labellum, 6.2–6.9 mm long, 1.3–1.8 mm wide, dilated in the distal half and narrowly winged at the apex, anterior surface below the middle furnished with a pink pubescent patch; apical margin of column sinuate or incised. *Stigma c.* 1.1 mm diam., depressed ovate to semicircular. *Anther* cap 1.3–1.5 mm long, 0.6–0.7 mm wide, rostrum decurved, small, apex projecting. *Pollinarium* 1.5–1.8 mm long; retinaculum *c.* 0.8 mm long, ovate; stipes *c.* 1.1 mm long; pollinia *c.* 0.7 mm long, obovoid, dark yellow. *Capsule* 11–15 mm long, 6–7 mm wide, prominently ribbed, cream to mauve or pale pink. (Figure 11)

Fig. 11. *Dipodium basalticum*. A–C. Habit. D. Inflorescence. E. Unidentified scoliid wasp pollinating flower. F–I. Flowers. J. Close-up of column and labellum base. K. close-up of labellum apex and column apex. Vouchers: A, D, I, J: *R.L.Barrett & M.D.Barrett RLB 748* (PERTH), B, C, E–I: not vouchered, from near Charnley River Station homestead. Photos by R.L. Barrett & M.D. Barrett (A, D, J, K); R. Maher (B, C, E–I).

Diagnostic characters: Allied to *D. stenocheilum*, differing in the smaller flowers with flecks and stripes and robust stem. Similar in appearance to *D. elegantulum*, differing in the tepals having obtuse rather than acute apices and a narrower (narrow rhomboid to narrow elliptical), more or less acute labellum.

Specimens examined: WESTERN AUSTRALIA: 0.5 km ESE of Beverley Springs Stn Hstd, 10 Feb. 1993, *M.D.Barrett 198* (PERTH); 0.5 km ESE of Beverley Springs Station Homestead, 16°43'10"S, 125°27'40"E, 29 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 748* (CANB, DNA, K, PERTH (2 sheets)); Airfield swamp, 4 km N of mining campsite, Mitchell Plateau N Kimberley, 7 Dec. 1982, *K.F.Kenneally 8663* (PERTH); Mitchell Plateau mining camp, 10 Dec. 1978, *J.Smith s.n.* (PERTH).

Distribution: Endemic to the Kimberley, first discovered on the Mitchell Plateau, and now known to be widely distributed from Theda and King Edward River Stations south to Beverley Springs (Charnley River) Station, but rarely seen and number of populations is difficult to assess. Known populations range from 5–50 plants.

Conservation status: Relatively poorly known, but difficult to locate, and given the range of distribution, probably more common than current collections indicate. Conservation Codes for Western Australian Flora: Priority 3 recommended.

Ecology: Occurs in open Eucalypt woodland dominated by *Eucalyptus tetrodonta* with *Erythrophleum* aff. *chlorostachys*, *Planchonia careya*, *Sorghum* sp. and *Terminalia canescens*.

Phenology: Flowering and fruiting December–February.

Etymology: The name is derived from the basalt-derived substrates the species grows on.

Notes: Previously confused with *D. stenocheilum* O.Schwarz. Differs from *D. elegantulum* in that the column hairs are restricted to the apical half of the column, not scattered along the entire length. Table 6 presents key data to distinguish the two Kimberley species from the two most morphologically similar species.

Common name: Flecked hyacinth orchid.

Table 6. Comparison of distinguishing morphological characters for *Dipodium ammolithum*, *D. stenocheilum*, *D. basalticum* and *D. elegantulum*.

	D. ammolithum	*D. stenocheilum s.l.*	*D. basalticum*	*D. elegantulum*
Stems	uniformly cream to purple vinaceous, to pink, purplish brown or dark mauve, straw-coloured in patches, dark pinkish purple (not flecked or streaked)	uniformly greenish or cream to pale pink (not flecked or streaked)	pale cream to purple, often suffused and flecked or streaked with pinkish purple	creamy white to greenish or sometimes dark pinkish purple (not flecked or streaked)
Tepals	adaxially uniform pale pink with the only markings a slightly darker pink midline and veins, abaxially very faintly speckled	white or pale pink to dark pink with darker small spots and striae outside, lighter pink inside with a few scattered spots	adaxially generally pale pink to white, usually with some small flecks and stripes of a darker shade, abaxially darker pink with scattered flecks of a darker shade, more prominent at the distal end	pale pink to dark pink with darker small spots and striae outside, lighter pink inside with a few large spots near the apex of the tepals
Dorsal sepal	12.5–16.4(–20.3) mm long, 1.0–2.5(–3.2) mm wide	20–22.5 mm long, 4.5–5.0 mm wide	11.2–14.8 mm long, 2.2–3.2 mm wide	(14–)15.5–23 mm long, (3.0–)4.0–6.0 mm wide
Lateral sepals	*Lateral sepals* 11.1–18.2(–20.9) mm long, 1.6–2.6(–2.9) mm wide	19.5–22.3 mm long, 4.3–4.8 mm wide	11–18 mm long, 2.3–3.0 mm wide	(15.0–)16.3–26 mm long, (2.5–)4.3–6.0 mm wide
Lateral petals	13.1–18.0(–27.6) mm long, 1.4–1.8(–3.2) mm wide	19.3–20.2 mm long, 3.8–5.2 mm wide	12.2–15.8 mm long, 2.4–2.8 mm wide	(13–)15.5–24 mm long, (2.5–)3.8–5.6 mm wide
Labellum	slightly incurved in the distal half, 7.8–12.6 mm long, 3.1–4.5 mm wide, dark pink	strongly recurved, appearing much narrower than it is: 17.8–18.2 mm long, 7.3–7.7 mm wide, dark pink	slightly incurved in the distal half, 12.3–20.5 mm long, 2.9–5 .7 mm wide, pale to dark pink	slightly incurved in the distal half, (14–)16.0–22.8 mm long, (4–)5.2–7.3 mm wide, dark pink
Labellum lateral lobes	pink, projected forwards, not out-curved when fresh, sometimes spreading when dry, equal to or slightly longer than column, 2.3–3.0 mm long, 0.7–0.8 mm wide, *c.* narrowly oblong	projected forwards, not out-curved when fresh, 3.2–3.8 mm long, oblong with rounded apex	lighter in colour than the midlobe, projected forwards, not out-curved when fresh, often spreading when dry, equal to or slightly longer than column, 3.4–3.8 mm long, 0.7–0.8 mm wide, *c.* narrowly oblong	projected forwards, upcurved when fresh, distinctly longer than column, 3.7–3.9(–6.0) mm long, 1.3–1.5(–2.0) mm wide, linear-spathulate

	D. ammolithum	*D. stenocheilum s.l.*	*D. basalticum*	*D. elegantulum*
Labellum midlobe	7.3–9.0 mm long, 2.6–3.1 mm wide, narrow rhomboid to narrow elliptical, more or less acute, furnished from about three quarters to the apex with a central band (for 3–4.5 mm), which is broadest at the distal end, of hairs which are more or less tangled, 0.4–0.6 mm long and purplish, minutely papillose (papillae *c.* 0.05 mm long) over most of length	*c.* 6–7 mm long, *c.* 4 mm wide, hairy along midline, held diagonally forward at *c.* 60° to margin, elsewhere glabrous or a few hairs near column along midline; longest hairs 0.6–0.8 mm long; also hairy in throat for last 4–5 mm	10–13 mm long, 2.4–3.0 mm wide, furnished from about two thirds to the apex with a central band, which is broadest at the distal end, of hairs which are more or less tangled, 0.2–0.4 mm long and generally mauve, with another patch of dense hairs at the base of the lobes	8.0–10.0 mm long, 4.0–5.0 mm wide, hairs on labellum in a band along central part with weak ridges, hairs sparse over middle portion between larger hairs and bumps, dense behind and around bumps, hairs extending onto lower margins of lateral lobes
Column	closely parallel to the labellum, 5.8–8.1 mm long, 1.6–2.4 mm wide, dilated in the distal half and narrowly winged at the apex, anterior surface below the middle furnished with a pink pubescent patch; apical margin of column sinuate or incised	closely parallel to the labellum, 8.1–9.5 mm long, 3.4–4.2 mm wide, dilated in the distal half and narrowly winged at the apex	closely parallel to the labellum, 6.2–6.9 mm long, 1.3–1.8 mm wide, dilated in the distal half and narrowly winged at the apex, anterior surface below the middle furnished with a pink pubescent patch; apical margin of column sinuate or incised	closely parallel to the labellum, 7.4–10.0 mm long, 3.3–3.3 mm wide, dilated in the distal half and narrowly winged at the apex, anterior surface below the middle furnished with a pink pubescent patch; apical margin of column with a few crenations
Disc [throat]	furnished with two sublinear pubescent keels 5.3–8.0 mm long, 0.5–0.7 mm wide which generally diverge at the distal end	furnished with two sublinear pubescent keels *c.* 1.2 mm long, firmly attached, only existing as raised ridges, or tips free for *c.* 0.35 mm	furnished with two sublinear pubescent keels 5.2–8.6 mm long, 0.6–0.9 mm wide which generally diverge at the distal end	furnished with two sublinear pubescent keels *c.* 7 mm long, *c.* 1 mm wide, firmly attached, only existing as raised ridges
Pollinia	*c.* 0.6 mm long, obovoid	not examined	*c.* 0.7 mm long, obovoid	0.8–1.0 mm long, obovoid
Vouchers	See specimens cited	*Cowie 8016* (DNA D136624)	See specimens cited	*B.Gray* 4940 (CNS); *Maslin* (CNS 12717)

Empusa Lindl., *Bot. Reg.* 10: sub t. 825 (1824). *Type*: *E. paradoxa* Lindl.

Notes: We here use Lindley's generic name *Empusa* as the definition of *Liparis* Rich. remains problematic. That genus has been widely demonstrated to be paraphyletic (Cameron 2005; Pridgeon *et al.* 2005; Tsutsumi *et al.* 2007; Li *et al.* 2013, 2020; Su *et al.* 2015; Tang *et al.* 2015; Kumar *et al.* 2022). Cameron (2005) in the first molecular phylogenetic analysis of Malaxideae demonstrated that the traditional interpretations of *Liparis* and *Malaxis* Sol. ex Sw. are both polyphyletic assemblages. While global sampling still has many gaps, it is clear that taxa currently included in *Liparis s. lat.* (sensu Ridley 1886), including in Australia, belong in multiple segregate genera (as proposed by Margońska & Szlachetko 2001, 2004; Margońska 2006; Li *et al.* 2020), though some authors still advocate for broad concepts of varying circumscription (Smith 1909; Blaxell 1978; Gray 1992; Seidenfaden 1992; Comber 2001; Schuiteman *et al.* 2001–2010; Jones & Clements 2004, 2005; Jones 2006, 2021; Jones *et al.* 2006, 2010; Bostock 2008; Chen *et al.* 2009; Li & Yan 2013; Zhou *et al.* 2016; Li *et al.* 2019; Aung *et al.* 2020; Gray *et al.* 2021).

Su *et al.* (2015), in a more detailed study based on analysis of 74 species of Malaxideae that included material of *Empusa habenarina*, reaffirmed the earlier work of Cameron (2005, demonstrating the paraphyly of *Liparis s. lat.*. Studies by Su *et al.* (2015) and Kumar *et al.* (2022) also revealed that *E. habenarina* does not align with *Liparis sens. str.*, rather it falls within a highly supported and well isolated group sister to and part of a major clade that includes genera such as *Crepidium* Blume, *Dienia* Lindl. and *Empusa* Lindl. This renders the name *Liparis s. str.* inapplicable to *E. habenarina* and to its relatives with similar general vegetative and floral morphology. However, a workable classification is yet to be achieved for the terrestrial clade of Malaxideae, which includes the types of *Crepidium*, *Dienia*, *Empusa* and *Liparis*. While the genus *Empusa* has been accepted in some recent publications, *Dienia* is an equally competing name for this clade, which also includes the later name *Crepidium*. *Empusa* is therefore the earliest available generic name applied to this taxon, though further changes can be expected to establish acceptable generic boundaries in tribe Malaxideae.

Empusa habenarina (F.Muell.) D.L.Jones & M.A.Clem., *The Orchadian* 14(8): xiv (2004). *Sturmia habenarina* F.Muell., *Fragm.* 4: 131 (1864). *Liparis habenarina* (F.Muell.) Benth., *Fl. Austral.* 6: 273 (1873). *Leptorchis habenarina* (F.Muell.) Kuntze, *Revis Gen. Pl.* 2: 671 (1891). *Type*: 'In pratis humidis ad sinum Rockingham's Bay', *J.Dallachy* s.n. (holo: K; iso BM 00090085!).

Illustrations: Nicholls, *Orchids Austr.* 100, t. 363 (1969), as *Liparis habenarina*; Dockr., *Austr. Indig. Orchids* 1 (edn. 2): 350, pl. p. 351 (1992), as *Liparis habenarina*; P.H.Weston in G.J.Harden, *Fl. New S. Wales* 4: 226, fig. (1993), as *Liparis habenarina*; T.Bishop, *Field guide orchids New S. Wales Vict.* 183, fig. 436 (1996), as *Liparis habenarina*; D.L.Jones, *Compl. Guide Austr. Orchids* 274, fig., pl. (2006); A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 394, 397 (2008), as *Liparis habenarina*; A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 475, 499 (2013), as *Liparis habenarina*; Liddle *et al.*, *Field Guide Pl. Darwin Sandsheet Heath* [20], pl. (2017); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 643 pl., fig. (2021).

Terrestrial *herb* to 50(60) cm tall, with a few clustered, subterranean pseudobulbs usually 2, 2–3 cm long, 1.5–2.5 cm wide, obovoid. *Leaves* usually three, 10–25 cm long, 2–4 cm wide, ovate, oblong or obovate, acute or obtuse, usually distinctly plicate, sometimes scarcely plicate, with (usually 5) prominent veins, bases sheathing stem. *Inflorescence* a terminal raceme, stiffly erect, 15–50(–60) cm tall; peduncle equal to or greatly exceeding the rachis, distinctly 4–6 angular and narrowly winged, usually a solitary bract at the base; rachis 8–22-flowered, bracts 3–4 mm long, pedicels, including ovary, 5–10 mm long. *Flowers* resupinate, 10–12 mm wide, greenish yellow or sometimes purple with a green column. *Dorsal sepal* deflexed, 5–10 mm long, 1–2 mm wide, more or less linear or lorate with the margins revolute. *Lateral sepals* deflexed, connate towards the base, sub-porrect in the proximal third then revolute, closely subtending labellum, oblong to cuneate, 6–8 mm long, *c.* 3 mm wide when flattened. *Petals* deflexed, 8–10 mm, *c.* 1 mm wide, linear to falcate-lorate. *Labellum* semierect to decurved through about 90°, 4–6 mm long 3–4 mm wide, oblong to obovate, shallowly canaliculate, sometimes bifid in the distal third, the lobes rounded and slightly serrulate or sinuate; disc with two narrow, slightly raised keels converging towards apex. *Column* prominent above sepals and petals, 4–5 mm long, curved through about 90° past the middle; wings rather large, more or less bluntly depressed triangular. *Stigma* transverse sub-oblong. *Rostellum* small and not very prominent. *Anther* subquadrate, with a long decurved deltoid rostrum. *Pollinia* sub-reniform in lateral view. *Capsule* erect, dehiscent, 10–12 mm long. (Figure 12).

Specimens examined: WESTERN AUSTRALIA: near falls at head of north arm of Bachsten Creek Gorge, Prince Regent River Reserve, 30 Jan. 1999, *M.D.Barrett, W.Maher & K.W.Dixon MDB 691* (PERTH); Edkins Ra., 78 km NNW of Beverley Springs Stn Hstd, 11 Jan. 1995, *R.L.Barrett & M.D.Barrett RLB 956* (PERTH); *c.* 8 km N of Charnley River Crossing on Walcott Inlet track, Edkins Range, 8 Jan. 2001, *R.L.Barrett & K.W.Dixon RLB 1660* (PERTH); 'Shrimp Creek' (informal name), 11.7 km S of Kings Cascades, Prince Regent River Reserve, 22 Jan. 2007, *R.L.Barrett & M.D.Barrett RLB 3745* (PERTH). NORTHERN TERRITORY: Melville Island, 15 km south of Snake Bay, 31 Jan. 1984, *D.L.Jones 1286* (CANB, DNA). QUEENSLAND: Moa Island, 1989, *D.L.Jones 3625* (CBG); near Herberton, 2002, *D.L.Jones 18321* (CANB). NEW SOUTH WALES: Woolgoolga, 23 Apr. 1992, *S.C.Clemesha s.n.* (NSW 429775); Brunswick Heads, Mar. 1935, *H.M.R.Rupp s.n.* (NSW 379241).

Distribution: Recorded from a relatively small area in the Edkins Range and upper Prince Regent River in the North Kimberley. Also occurs on Melville Island and the northern mainland in the Northern Territory, more widespread in Queensland, from Cape York southwards, extending to Coffs Harbour in New South Wales. Possibly also in Asia (see notes).

Conservation status: Known only from four sites within the Edkins Range, at least two of which are subject to disturbance by feral pigs, and two on the Gardner Plateau, and it remains poorly known in Western Australia. Conservation Codes for Western Australian Flora: Priority 2 (Western Australian Herbarium 1998 onwards). Listed as Data Deficient in the Northern Territory.

Ecology: Grows in seasonally wet, sandy / peaty soils in association with *Banksia dentata*, *Byblis liniflora*, *Calochilus barbarossa*, *C. kimberleyensis, Clitoria australis*, *Didymoplexis pallens*, *Drosera paradoxa*, *Eucalyptus apodophylla*, *E. houseana*, *E. alba*, *Eulophia bicallosa*, *Haemodorum flaviflorum*, *Hypoxis nervosa, Lindernia plantaginea, Ludwigia octovalvis*, *Melaleuca viridiflora*, *Pandanus spiralis* var. *spiralis, Pecteilis eurystoma*, *Stylidium pachyrrhizum, Utricularia uliginosa* and *Xyris complanata*.

Fig. 12. *Empusa habenarina*. A, B. Habit. C. Pleated leaves. D. Inflorescence. E–J. Flowers. K. Fruit. Vouchers: A: *R.L.Barrett & M.D.Barrett RLB 956* (PERTH); B–K: *R.L.Barrett & M.D.Barrett RLB 3745* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Phenology: Flowers and fruits recorded for January (to April in the Northern Territory and Queensland).

Affinities: Closely related to *Liparis wenshanensis* Y.Y.Su, Y.L.Huang & G.Q.Zhang, *L. ferruginea* Lindl. and possibly *L. sootenzanensis* Fukuyama (Su *et al.* 2015). *Liparis wenshanensis* differs in having 45–55 flowers; white sepals, petals and column; strongly recurved lateral sepals and a cordate lip. *Liparis ferruginea* is morphologically very similar, but the wings on the column are much broader in *Empusa habenarina*. *Liparis sootenzanensis* differs in having broader dorsal sepals, filiform petals and a denticulate apex to the lip.

Notes: This species may extend to Asia, in which case there may be an earlier name available. The illustration of *Liparis odorata* Lindl. in Smith (1908; fig. 201) from Java appears to be a good match for this taxon, but Smith's concept does not match *L. odorata*, a species described from India. Smith's illustration could otherwise represent *L. ferruginea* Lindl.

Common names: Hobgoblin orchid, Kimberley mosquito orchid.

Eulophia R.Br., *Bot. Reg.* 7: ad t. 573 (Oct. 1821), (as '*Eulophus*'), *nom. et orth. cons. Type*: *E. guineensis* Lindl., *typ. cons.*, designated by W.Greuter, *Regnum Veg.* 118: (1988).

Geodorum Jackson in Andrews, *Bot. Repos.* 10: t. 626 (1811), *nom. rej. prop. Type*: *G. citrinum* Jackson.

Eulophia R.Br. ex Lindl., *Bot. Reg.* 8: t. 686 (1822). *Type*: *E. guineensis* Lindl.

Graphorkis Thouars, *Nouv. Bull. Sci. Soc. Philom Paris* 1: 318 (1809), *nom. rej. Type*: not designated.

Wolfia Dennst., *Schlüssel Hortus Malab*. 38 (1818), *non* Schreb. (1791), *nom. illeg. Type*: *W. spectabilis* Dennst.

Eulophia C.Agardh, *Aphor. Bot*. 109 (1822) (Musci), *nom. rej*.

Lissochilus R.Br., *Bot. Reg*. 7: sub t. 573 (1821), *nom. rej. Type*: *L. speciosus* R.Br.

Cyrtopera Lindl., *Gen. Sp. Orchid. Pl*. 189 (1833). *Lectotype*: *C. woodfordii* (Sims) Lindl., designated by A.Richard, *Orbigny, Dict. Univ. Hist. Nat*. 4: 561 (1844).

Thysanochilus Falc., *Proc. Linn. Soc. London* 1: 14 (1839). *Type*: not designated.

Hypodematium A.Rich., *Tent. Fl. Abyss*. 2: 286 (1850), *non* Kunze (1833) *nec* A.Rich. (1848), *nom. illeg. Type*: *H. abyssinicum* A.Rich.

Platypus Small & Nash in Small, *Fl. S.E. U.S.*: 329 (1903). *Type*: *P. papilliferus* Small & Nash.

Donacopsis Gagnep., *Bull. Mus. Natl. Hist. Nat.*, sér. 2, 4: 593 (1932). *Type*: *D. laotica* Gagnep.

Semiphajus Gagnep., *Bull. Mus. Natl. Hist. Nat.*, sér. 2, 4: 598 (1932). *Type*: not designated.

Notes: Since its description by Brown (1821), definition of the genus *Eulophia* has remained problematic, and much work is still required at regional levels (e.g. Ortúñez *et al*. 2020). The best circumscription is still a matter of debate, but molecular data clearly demonstrate the need to combine *Eulophia s str*. with the earlier name *Geodorum* Jackson as the type species of both genera are resolved in the same clade (Batista *et al*. 2014; Martos *et al*. 2014; Bone *et al*. 2015). This combination of the two genera was foreshadowed by Schlechter (1914 [transl. 1982]) who stated that '..there is no characteristic by means of which it is possible to separate *Geodorum* from *Eulophia* R. Br., yet it has not occurred to any botanist to unite these two genera.'

Chase *et al*. (2021a) have provided new combinations for former *Geodorum* species in *Eulophia*, but many species circumscriptions remain problematic and a detailed revision is required. While *Geodorum* is the earlier name, Chase *et al*. (2021b) formally proposed conservation of *Eulophia* as there are many more species currently included in that genus. Ormerod (2017) had anticipated such a proposal, and provided the new combination *Eulophia picta* (R.Br.) Ormerod. With the exception of *Eulophia picta*, other Australian species are relatively poorly collected, in part due to the flowers and leaves emerging at different times, and flowering prior to or early in the wet season when few other species are in flower, and weather is inhospitable for field work. Some vegetative characters of Australian species are discussed by Holttum (1952), but further work is required.

Eulophia bicallosa (D.Don) P.Hunt & Summerh., *Kew Bull*. 20: 60 (1966); *Bletia bicallosa* D.Don, *Prodr. Fl. Nepal*. 30 (1825); *Limodorum bicallosum* Buch.-Ham. ex D.Don, *Prodr. Fl. Nepal*. 30 (1825), *nom. inval., pro. syn*.; *Graphorkis bicallosa* (D.Don) Kuntze, *Revis. Gen. Pl*. 2: 662 (1891); *Liparis bicallosa* (D.Don) Schltr., *Repert. Spec. Nov. Regni Veg. Beih*. 4: 196 (1922). *Type*: Terriany Forest, lower Nepal, 30 Mar. 1802, *F.Buchanan-Hamilton s.n*. (lecto: BM 000525392; isolecto: LINN 1402.8; K 000852989), designated by Ormerod, *Checkl. Papuasian Orch*. 292 (2017).

Epipactis bicarinata Buch.-Ham. ex Wall., *Numer. List* 7363 (1831), *nom. nud*.; *Cyrtopera bicarinata* Lindl., *Gen. Spec. Orchid. Pl*. 190 (1833); *Eulophia bicarinata* (Lindl.) Hook., *Fl. Brit. India* 6: 6 (1890); Lindl., *Gen. Sp. Orchid. Pl*. 190 (1833); *Graphorkis bicarinata* (Lindl.) Kuntze, *Revis. Gen. Pl*. 2: 622 (1891). *Type*: Nepal: Patgang, 23 Mar. 1809, *F.Buchanan-Hamilton s.n*. (holo: K-Wall.; iso: K-Lindl.).

Cyrtopera candida Lindl., *J. Proc. Linn. Soc., Bot*. 3: 31 (1864); *Eulophia candida* (Lindl.) Hook.f. in J.D.Hooker, *Fl. Brit. India* 6: 6 (1892); *Graphorkis candida* (Lindl.) Kuntze, *Revis. Gen. Pl*. 2: 662 (1891). *Type*: Sikkim, *Cathcart*, *J.D.Hooker 241* (holo: K 000078326).

Eulophia fitzalanii F.Muell. ex Benth., *Fl. Austr*. 6: 300 (1873); *Graphorkis fitzalanii* (Benth.) Kuntze, Revis. Gen. Pl. 2: 622 (1891). *Type*: Queensland: Mount Dryander, Jan. 1871, *E.F.A.Fitzalan s.n*. (holo: K 000078348; iso: MEL 677527).

Cyrtopodium parkinsonii F.Muell. ex Kraenzl., *Oesterr. Bot*. Z. 44: 256 (1894). *Type*: Papua New Guinea: Bismarck Archipelago, New Britain, near Ralum, 1885, *R.Parkinson 56* (holo: B†; iso: MEL 2420356, MEL2420357).

Cyrtopera formosana Rolfe, *Bull. Misc. Inform*. 1896: 198 (1896); *Eulophia formosana* (Rolfe) Rolfe in Forbes & Hemsley, *Enum. Pl. China, Orchids* 28 (1903). *Type*: China: South Cape, Formosa, *A.Henry 1947* (holo: NY00008694, image seen, iso: K 000078314).

Eulophia bicarinata var. *major* King & Pantl., *Ann. Roy. Bot. Gard*. (*Calcutta*) 8: 181 (1896); *Eulophia bicallosa* var. *major* (King & Pantl.) Pradhan, *Indian Orchids: Guide Identif. & Cult*. 2: 461 (1979). *Type*: n.v.

Eulophia versteegii J.J.Sm., *Bull. Dept. Agric. Indes Neerl.* 19: 24 (1908). *Type*: New Guinea: pre 1908, *G.M.Versteeg* 1952 (holo: *n.v.* iso: K 000078345 (ex BO), L 0063896, images seen).

Eulophia neopommeranica J.J.Sm., *Nova Guinea* 8(1): 26 (1909). *Eulophia papuana* (Kraenzl.) Schltr. in K.Schum. & Lauterb., *Nachtr. Fl. Deutsch. Schutzgeb. Südsee* 148 (1905); *Cyrtopera papuana* Kraenzl., *Notizbl. Bot. Gart. Berlin-Dahlem* 2: 104 (1898), *nom. illeg.*, *non* Ridl. (1886). *Type*: Papua New Guinea: Ralum, im Grasfeld auf vulkanischem Boden 100 m ü. M., Oct. 1896, *Dahl 90* (holo: B†).

Eulophia brachycentra Hayata, *Icon. Pl. Formosa*. 4: 72, fig. 36a (1914). *Type*: Formosa [Taiwan]: Taitō: Shinkögai, June 1906, *Z.Kobayashi s.n.* (holo: TAI, *n.v.*).

Eulophia vanoverberghii Ames, *Philipp. J. Sci.* ser. C, 7: 13 (1914). *Type*: Philippines: Bontoc subprovince, Luzon, April 1910, *M.Vanoverbergh* 336 (holo: AMES ; iso: K 000078344, images seen).

Eulophia merrillii Ames, *Orchidaceae* 5: 104 (1922). *Type*: Philippines: Caraga, Surigao Province, Mindanao Island, 6 October 1906, *E.D.Merrill* 5452 (holo: AMES 00099460, image seen).

Eulophia venosa auct. non (F.Muell.) Rchb.f. ex Benth.: W.Fitzg., *J. & Proc. Roy. Soc. West. Austr.* 3: 129 (1918); A.S.George, *Nuytsia* 1: 182 (1971).

Illustrations: ?D.L.Jones, *Native Orchids Austr.* 362, fig. (1988); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1010, fig. 303e (1992); Dockr., *Austr. Indig. Orchids* (edn. 2): 2: 812, fig. p. 813 (1992); A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 382, 385, 386, 389 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 472, 490, 491 (2013); ?D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 624 pl., fig. (2021); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 628, pl. (2021).

Terrestrial, geophytic *herb*, deciduous, tuberous rhizoids up to 10 cm long, to 3 cm diam., forming chains of up to 5, each representing a year's growth, whitish. Leaf-bearing *stem* 150–250 mm long, usually with 3 large sheathing bracts, the upper bract large and leaf-like. *Leaf* solitary, lanceolate to very narrowly ovate, finely plicate, 250–400 mm long, 10–25 mm wide. *inflorescence* a terminal raceme with 5–22 flowers, 60–80(–120) cm high, the peduncle generally much longer than the rachis. *Flowers* 20–30 mm diam., pale green or whitish with variable purple, red or brownish dusting or striping; with a green or deep purple or red column foot; pedicels including the ovary 10–30 mm long. *Dorsal sepal* narrowly ovate, acute, 10–15 mm long, 2.5–4 mm wide. *Lateral sepals* adnate with column foot, widely spreading, oblong, 13–19 mm long, 3.5–5 mm wide, apex decurved, sometimes twisted in distal half. *Petals* projected forward, obovate to broadly lanceolate, 10–15 mm long, 5–6 mm wide, often apiculate. *Labellum* distinctly 3-lobed, up to 15 mm long, 10 mm wide, keels *c.* 5 mm long, glabrous; spur *c.* 3 mm long, subconical, obtuse lateral lobes 2–3 mm long, 7–9 mm wide, with raised purple or red veins; midlobe more or less truncate, recurved, 6–8 mm long, 7–10 mm wide, with fine purple or red veins, the central basal portion rugose, margins undulate and suberect. *Column* 6–7 mm long, projected forward, curved; foot *c.* 4 mm long. *Stigma* sub-reniform. *Anther* with a deflexed, truncate rostrum. *Pollinia* obovate, stipe short, narrow. *Rostellum* small, truncate. *Capsule c.* 15 mm long, 8 mm wide. (Figure 13).

Specimens examined: WESTERN AUSTRALIA: Edkins Ra., 62 km N of Beverley Springs Stn Hstd, 26 Dec. 1995, *R.L.Barrett & M.D.Barrett RLB 634* (PERTH); Edkins Ra., 78 km NNW of Beverley Springs Stn Hstd, 11 Jan. 1995, *R.L.Barrett & M.D.Barrett RLB 957* (PERTH); Edkins Ra., 62 km N of Beverley Springs Stn Hstd, 8 Jan. 2001, *R.L.Barrett & K.W.Dixon RLB 1649* (CANB, PERTH); between Isdell and Precipice Ranges, 21 Sept. 1905, *W.V.Fitzgerald 1498* (PERTH); Artesian Range, 30 Sept. 1921, *C.A.Gardner 1365 / 1865* (PERTH).

PAPUA NEW GUINEA: near Horanda airstrip, Northern Division, Territory of Papua, 4 Sept. 1953, *R.D.Hoogland 3808* (CANB); Milne Bay: Near Medino village, N coast of Cape vogel Peninsula, 6 Sept. 1954, *R.D.Hoogland 4645* (CANB).

Distribution: North Kimberley, Isdell, Precipice and Edkins Range, Mt Fyfe and Theda Station in Western Australia, and from Cape Tribulation south to Mackay in North Queensland. Possibly also in the Northern Territory but those records probably represent a distinct taxon (see Jones 2021). As currently broadly defined, this species is widespread outside Australia from New Guinea to the Philippines, China, Nepal and India.

Conservation status: In the Kimberley, restricted in distribution, and potentially threatened by grazing and burning pressures. Locally abundant at some locations and probably not under immediate threat, however, individual habitats are quite small and thus increasing pig numbers are having a direct impact and pose an increasing threat to most known populations. Frequent fire will also likely shrink habitat availability through the loss of soil organic matter. This species may become threatened if habitat modification by feral animals and fire is not abated. Loss of organic matter through burning, resulting in habitat loss, is likely to be a medium-term (10–20 years) threat to the species. Conservation codes for Western Australian flora: Priority 3 recommended.

Fig. 13. *Eulophia bicallosa*. A, B. Habit. C. Pseudobulbs. D. Habitat and habit. E–H. Inflorescence. I–K. Flowers. Vouchers: A–C: near Charnely River *R.L.Barrett & K.W.Dixon RLB 1649* (PERTH); D, F–H, J, K: not vouchered, same site as A–C. E, I: not vouchered, Theda Station. Photos by R.L. Barrett (A–C) & R. Maher (D–K).

Ecology: Occurs in peaty, humus-rich, otherwise sandy and seasonally waterlogged soil amongst long grass.

Phenology: Flowers August–December (predominantly seen following fire when plants are more easily located).

Affinities: Similar to *E. venosa* F.Muell. from adjacent areas of the Northern Territory which differs in the prominently veined sepals and petals, and the labellum being longer than wide. As some recent collections from the Kimberley are sterile, their identity is not proven and they may be referrable to *E. venosa*.

Notes: Collected by W.V. Fitzgerald from between the Isdell and Precipice Range in 1905 (Fitzgerald 1918) and by C.A. Gardner from the Artesian Range in 1919 (Gardner 1923), only three other specimens had been collected from Theda Station, until January 1995 when plants in the leaf stage were found in their thousands on sandflats in the Edkins Range, Theda and Doongan (King Edward River) Stations. There are two flower forms known in the Kimberley region, one with a predominantly green labellum and one with a predominantly pink labellum, but there are too few specimens available to know if they represent discrete taxa or local or seasonal variation.

The application of names in *Eulophia* is still problematic and further assessment across the range of the genus is still required (Bone *et al.* 2015; Ormerod 2017; Ortúñez *et al.* 2020). There are still few flowering specimens from Australia available in herbaria as flowering occurs with the first monsoon rains, when little collecting effort occurs. High levels of clonality within populations may also lead to high levels of localised variation

that could create false impressions of speciation. It is still quite possible that the name *E. bicallosa* (*sensu* Hunt & Summerhayes 1966) should not be applied to Australian populations (see Gogoi *et al.* 2012 for photos from Assam, India), but further study is required. Likewise, the Kimberley and Queensland populations may represent independent dispersals from Asia, and may not be conspecific.

The apparent disjunct distributions in the Kimberley and in Queensland may suggest independent dispersal events from south-east Asia.

Common name: Tropical grass orchid, Frilled lip orchid.

Eulophia picta (R.Br.) Ormerod, *Checkl. Papuasian Orch.* 293 (2017); *Cymbidium pictum* R.Br., *Prodr.* 331 (1810); *Geodorum pictum* (R.Br.) Lindl., *Gen. Sp. Orchid. Pl.* 175 (1833), *nom. illeg. non* Link & Otto (1821). *Type*: Australia: Northern Territory: Dec. 1802, *R.Brown* [*Bennett No. 5507*] (lecto: BM 000525343, designated by Hallé, *Fl. Nouv. Caledonie* 8: 250 (1977), (as 'holo'); isolecto K 000890997).

Geodorum semicristatum Lindl., *Fol. Orchid.* 6: 2 (1854). *Type*: Philippines: 1841, *H.Cuming* 2107 (holo: K-LINDL; iso: BM 000525330; K 000890999, K 000891000).

Tropidia grandis Hance, *J. Linn. Soc., Bot.* 13: 128 (1873). *Type*: China: Guangdong: Hong Kong, in the Happy Valley woods, July 1866, *H.F.Hance* 13343 (holo: BM 000525308).

Geodorum pacificum Rolfe, *Bull. Misc. Inform. Kew* 1908: 71 (1908). *Type*: Polynesia: Vaua, Tonga Islands, Jan. 1892, *C.S.Crosby 246* (syn: K 000890995); Solomon Islands, Jan. 1907, *C.M.Woodford s.n.* (syn: K 000890996, L, *n.v.*).

Geodorum neocaledonicum Kraenzl., *Vierteljahrsschr. Naturf. Ges. Zurich* 74: 82 (1929). *Type*: New Caledonia, pentes du Tiebaghi, Paagoumene, 12 Mar. 1925, *A.Ü.Däniker 1384* (holo: Z; iso: Z).

Geodorum neocaledonicum Schltr. *nom. nud., nom. illeg. non* Kraenzl.: D.L.Jones, *Native Orchids Austr.* 364 (1988); E.M.Ross in T.D.Standley & E.M.Ross, *Fl. S.E. Queensl.* 3: 371 (1989); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1010 (1992); T.Bishop, *Field guide orchids New S. Wales Vict.* 196 (1996).

Geodorum terrestre auct. non (L.) Garay: Garay, *Harvard Pap. Botany* 2: 47 (1997).

Illustrations: R.Schlechter, *Orchidac. German New Guinea* 492, fig. (1914 [transl. 1982]), as *Geodorum pictum*; N.Hallé, *Fl. Nouv. Caledonie* 8: 224, pl. 106 (1977), as *Geodorum pictum*; D.L.Jones, *Native Orchids Austr.* 364, pl. p. 40, pl., fig. (1988), as *Geodorum neocaledonicum*; E.M.Ross in T.D.Standley & E.M.Ross, *Fl. S.E. Queensl.* 3: 371, fig. 56b (1989), as *Geodorum neocaledonicum*; A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1010, fig. 303f (1992), as *Geodorum neocaledonicum*; P.H.Weston in G.Harden, Fl. New S. Wales 4: 238, fig. (1993), as *Geodorum densiflorum*; T.Bishop, *Field guide orchids New S. Wales Vict.* 196, fig. 477 (1996), as *Geodorum neocaledonicum*; D.L.Jones, *Compl. Guide Austr. Orchids* 360, fig., pl. (2006); A.P.Brown *et al. Orchids West. Austr.,* figs p. 388, (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 470, 475, 492, 493 (2013), all as *Geodorum terrestre*; D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 630 pls, fig. (2021), as *Geodorum densiflorum*.

Terrestrial, geophytic *herb*, deciduous, often forming small vegetative clumps; pseudobulbs crowded, broadly ovoid, half or completely buried in ground, 2.5–4.5 cm diam. *Leaves* 3–5, petioles 2–8 cm long; lamina ovate to obovate 150–370(–450) mm long, 40–60(–90) mm wide, plicate, with distinct ribs and veins, attenuate, margins sometimes undulate, acuminate; leaves and inflorescences developing simultaneously. *Inflorescence* an axillary raceme, up to 400 mm high at anthesis, erect while developing, rachis reflexed 180° as flowers mature then straightening and elongating up to 700 mm long after fertilisation; peduncle with several bracts, the lower ones large and sheathing. *Flowers* 8–20, crowded, resupinate, depressed tubular, only partially open at the orifice only, 10–20 mm long, pink or purplish, with prominent dark red to purple veins and spots inside; pedicels short, 3–10 mm long, subtending bracts 5–15 mm long, 3–4 mm wide, narrowly triangular. *Dorsal sepal* 11–18 mm long, 3–5 mm wide, lanceolate. *Lateral sepals* free, 11–18 mm long, 2.5–4 mm wide, lanceolate, cymbiform at the apex, keeled on the outside. *Petals* 11–18 mm long, 2.5–4 mm wide, oblong or obovate, acute. *Labellum* obscurely 3-lobed, pink with red or purple veining, 10–15 mm long, 6–8 mm wide, saccate, emarginate; lateral lobes 5 mm long, 1 mm wide, recurved around the column; midlobe 2–3 mm long, 4 mm wide, margins slightly recurved and sinuate; keel extending onto the midlobe, *c.* 1 mm wide. *Column* 3–6 mm long, 2.5–3.5 mm wide, wings rudimentary, column foot 1–2 mm long. *Anther* hemispheric; pollinia large, grooved, stipe very short. *Rostellum* very small, narrow ovate. *Capsule* pendulous, somewhat fleshy when green, thickly ribbed, 25–50 mm long, 15–25 mm wide, obovoid, dehiscent. (Figure 14).

Fig. 14. *Eulophia picta*. A, B. Habit. C. Pleated leaf. D. Infructescence. E–H. Inflorescence. I–K. Flower. Vouchers: A–D: *R.L.Barrett RLB 4658* (PERTH); E–K: not vouchered, cultivated at Kings Park & Botanic Garden, from Synnot Range. *R.L.Barrett & M.D.Barrett RLB 699* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Specimens examined: WESTERN AUSTRALIA: Grevillea Gorge, 30 km NW of Beverley Springs Hstd, 7 June 1992, *M.D.Barrett 22* (PERTH); Gwen's Gorge, Edkins Ra., 85 km N of Beverley Springs Stn Hstd, 11 Jan. 1993, *R.L.Barrett* & *M.D.Barrett RLB 449* (PERTH); Grevillea Gorge, Synnot Ra., 32 km NW of Beverley Springs Stn Hstd, 14 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 699* (PERTH); Synnot Ra., 25 km NW of Beverley Springs Stn Hstd, 14 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 715* (PERTH); 'Skull Creek' camp and trap site, Doongan Station, 24 Apr. 2008, *R.L.Barrett RLB 4658* (PERTH); South Bachsten Creek, NW of falls on N side of creek in small gully, Prince Regent Nature Reserve, 21 Jan. 2010, *R.L.Barrett & V.Kessner RLB 6311* (PERTH); N side of Synnot Range, NW of Potts Camp, Charnley River Station, 28 Jan. 2010, *R.L.Barrett, M.Maier & P.Kendrick RLB 6568* (PERTH); near homestead, Charnley River Station [introduced from Synnot Range], 29 Jan. 2010, *R.L.Barrett RLB 6586* (PERTH); Mount Daglish Vine Thicket in Harding Range, W Kimberley, June 1987, *G.J.Keighery* & *J.J.Alford s.n.* (PERTH); Camp Creek, Mitchell Plateau, NW Kimberley, 03 Feb. 1979, *K.F.Kenneally 6972* (PERTH); 6 km S of Mining Camp in Crusher Vine thicket, Mitchell Plateau, N Kimberley, 25 Jan. 1989, *K.F.Kenneally* & *B.P.M.Hyland KFK 10843* (PERTH); 6 km N of Lake Gilbert near Beverley Springs, Kimberley, 01 Feb. 1989, *K.F.Kenneally* & *B.P.M.Hyland KFK 10938* (PERTH); SE of Mitchell Plateau mining camp, 7 Jan. 1979, *J.Smith s.n.* (PERTH 251925). NORTHERN TERRITORY: 13 km S of Gove Airport Terminal, 25 Feb. 1994, *K.Brennan 2686* (DNA); Melville Island, 'The Pines', 2 km past Taracumbie Falls turnoff, 31 Jan. 1984, *D.L.Jones 1289* (CANB, DNA); Angalarri River, 14 May 1994, *P.Latz 10002* (DNA); 10 km S of Maningrida, 18 June 1987, *D.Lucas 2608 & J.Russell-Smith* (DNA); Nightcliff, 14 Dec. 1964, *A.N.Rodd 19*

(NSW). QUEENSLAND: near Caloundra, 1997, *G.N.Batianoff 970115* (BRI, NSW); Bells Creek, near Golden Beach, S of Caloundra, Jan. 1985, *D.L.Jones s.n.* (CANB 665203); NW of Miram Vale, 1990, *P.H.Weston 1538 & P.G.Richards* (NSW). NEW SOUTH WALES: near Brunswick Heads, 1934, *F.Fordham 329* (NSW).

NEW CALEDONIA: *c.* 7 km from top of range on road from coast to Ouegoa, 24 Aug. 1992, *M.A.Clements 7925* (CBG); track from Baie d'Upi to Baie d'Oro, Ile des Pins, 10 Feb. 1991, *K.L.Wilson 7830 & P.H.Weston* (NSW).

Distribution: Widespread in vine thickets and rainforest in the North Kimberley, from Charnley River (Beverley Springs) and Pantijan Stations north to the Mitchell Plateau and Theda Stations. Widespread across the top end of the Northern Territory, north and eastern Queensland, and south as far as the north east coast of New South Wales. Also widespread in tropical Asia, New Guinea, Philippines, Japan and many Pacific islands including Solomon Islands, Samoa, Tonga, Vanuatu and New Caledonia.

Conservation status: Common in vine thickets over sandstone in the north-west Kimberley and not under threat.

Ecology: Occurs in vine thickets over sandstone or basalt, preferring damp areas with a thick litter layer in the Kimberley, more, rarely among ferns and grass near creeks with *Syzygium eucalyptoides*, *Typhonium peltandroides*, *Glycosmis sapindoides* and *Diospyros* sp. Also in open forests, woodlands, heathlands and grasslands in higher rainfall zones elsewhere in Australia.

Phenology: Flowers December–February, fruits January–March.

Affinities: Species limits in the clade formerly called *Geodorum* remain poorly understood. We accept the taxon first described as *Cymbidium pictum* R.Br. (Brown 1810) as the earliest available name for the widespread Australasian and Pacific species (e.g. Lewis & Cribb 1991). *Eulophia picta* may be most closely related to *E. cernua* (Willd.) T.C.Hsu (formerly *Geodorum densiflorum* (Lam.) Schltr.) from Asia, a species with more open flowers and few distinct internal markings, and *E. picta* is here regarded as a distinct species.

Notes: Incorrectly cited by Jones (1988), Ross (1989) and Wilson (1992) as '*G. neocaledonicum* Schltr.' [= *G. neocaledonicum* Kraenzl.].

While the name *Geodorum terrestre* (Linnaeus) Garay has been used in Australia following Garay (1997), the name was misapplied as the type of that name applies to *G. citrinum* Jackson (see Ormerod 1994, 2017; Chen *et al.* 2009; Averyanov *et al.* 2018; Chase *et al.* 2021b).

Hallé (1977) cited a holotype for *Geodorum pictum*, however this is to be corrected to lectotype, as it is the first designation of a single specimen from the original material. Many additional synonyms are listed by Naive *et al.* (2022), however this group of species requires significant additional work to determine the correct application of each of these names.

Common names: Shepherds crook orchid, Pink nodding orchid, Bent orchid.

Habenaria Willd., *Sp. Pl.* 4(1): 5, 44 (1805); *Habenorkis* Du Petit-Thouars, *Nouv. Bull. Sci. Soc. Philom. Paris* 1: 317 (1809), *nom. inval. Type*: *Orchis habenaria* L. (= *Habenaria macroceratilis* Willd.), designated by Kraenzl., *Bot. Jahrb. Syst.* 16: 58 (1892).

Mesicera Raf., *Neogenyton* 4 (1825). *Type*: *M. quinqueseta* Raf.

Nemuranthes Raf., *Fl. Tellur.* 2: 61 (1837), *nom. superfl. Type*: *N. habenaria* (L.) Raf.

Notes: Generic boundaries in subtribe *Habenarinae* remain problematic as current sampling in molecular phylogenies remains patchy for this highly diverse and pantropical clade of Orchids (Jones 1997; Bateman *et al.* 2003; Szlachetko *et al.* 2003; Szlachetko & Kras-Lapinska 2003a, 2003b, 2003c; Szlachetko & Sawicka 2003; Szlachetko 2003, 2005, 2012; Szlachetko & Kras 2006; Chen *et al.* 2009; Kurzweil 2009; Batista *et al.* 2013, 2014; Ngugi *et al.* 2020; Kolanowska *et al.* 2021). For Australia, only *H. hymenophylla* and *H. maccraithii* Lavarack are likely to remain in *Habenaria*, and possibly even these may be removed at a later date. Most Australian species are now placed in *Pecteilis* Raf. following recent resolution of relationships among Asian and Australian species using molecular data (Jin *et al.* 2014, 2017; see Clements & Jones 2018; Jones & Clements 2019).

Habenaria hymenophylla Schltr., *Repert. Spec. Nov. Regni Veg. Beih.* 9: 212 (1911). *Type*: Northern Territory: Near Port Darwin, 1888, *M.Holtze 799* (holo: B†; iso MEL 108305).

Habenaria trinervia auct. non Wight: Benth., *Fl. Austral.* 6: 394 (1873).

Illustrations: Dockr., *Austr. Indig. Orchids* 1: 28, fig. (1969); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 475, 495 (2013); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 603 pl., fig. (2021).

Erect, geophytic *herb* to 45 cm tall, glabrous. *Tuberoids* cylindrical to ovoid to obovoid. *Stems* with 5–8 scattered leaves and 2 or 3 sheathing bracts near the base. *Leaves* suberect, lamina 30–60 mm long, 30–35 mm wide, ovate or elliptical, thin-textured, margins entire to undulate, base sheathing the stem, acute or apiculate. *Inflorescence* a terminal raceme, erect, 10–25 cm long, 20–30-flowered although the flowers not crowded; bracts *c.* 15 mm long, ovate, shortly acuminate; ovaries *c.* 15 mm long, twisted, fusiform. *Flowers* resupinate, spreading-erect, hooded, 15–18 mm long, 10-13 mm wide, green and white. *Dorsal sepal* erect, incurved, hooded, 4.5–5 mm long, 4.5–5 mm wide, broadly ovate. *Lateral sepals* free, deflexed from the base, oblique, 4.5–5 mm long, 3.5–4 mm wide, margins incurved, ovate to oblong, apiculate. *Petals* suberect, divided into 2 lobes; posterior (upper) lobe oblique or out-curved, *c.* 6 mm long, 1.5 mm wide, linear, obtuse; anterior (lower) lobe incurved erect, *c.* 4.5 mm long, *c.* 1 mm wide, narrow linear. *Labellum* deeply 3-lobed; lateral lobes spreading or divergent at *c.* 30° to midlobe, variously curved, 4.5–7 mm long, 0.5 mm wide, narrow linear; midlobe incurved, 6–7.5 mm long, 1 mm wide, broad linear, obtuse; spur 11–15 mm long, somewhat curved forwards, ± cylindrical but dilated in distal third. *Column*, including the anther, *c.* 3.5 mm long, 2.5 mm wide; auricles *c.* 1 mm long. *Stigmatophores c.* 2 mm long, canaliculate dorsally. *Rostellum* triangular, carnose. *Thecal tubes* slightly shorter than the stigmatophores. *Pollinia* concave-cylindrical. *Capsule* erect, dehiscent. (Figure 15)

Fig. 15. *Habenaria hymenophylla*. A, B. Habit. C. Aerial rosette of leaves. D. Budding inflorescence. E–J. Flowers. Voucher: *R.L.Barrett, P.Kendrick & G.Sparkes RLB 6350* (PERTH). Photos by R.L. Barrett.

Specimens examined: WESTERN AUSTRALIA: Pitta Gorge, Prince Regent Nature Reserve [precise locality withheld], 23 Jan. 2010, *R.L.Barrett, P.Kendrick & G.Sparkes RLB 6350* (CANB, DNA, PERTH). NORTHERN TERRITORY: Arnhem Land district; Elcho Island: '10-mile area', on coast N of Wurrpan, 4 Feb. 1978, *M.A.Clements 1162* (CBG); Melville Island, 5 km W Snake Bay, 17 Apr. 1987, *J.Russell-Smith 2093* (DNA); Milingimbi, Arnhem Land, 18 Mar. 1987, *N.M.Smith 3474* (DNA); 1.5 km W of Humpty Doo, 6 June 1991, *S.Taylor 70* (DNA).

Distribution: In Western Australia, this species is only known from a single location in the north Kimberley, from a deep gorge near the Prince Regent River, very disjunct from the closest known populations in the Northern Territory. Its primary distribution is on Melville Island and near Darwin in the Northern Territory and from the Iron Range south to Rockhampton in Queensland.

Conservation status: The single known location in Western Australia is within the Prince Regent National Park. Recommended for listing as Priority two for Western Australian flora as the known locality is within a conservation reserve and not immediately threatened. Only about 30 plants have been observed over a distance of about 200 m. Listed as Data Deficient in the Northern Territory. http://eflora.nt.gov.au/factsheet?id=4082

Ecology: In the Kimberley, found growing in deep leaf litter under gallery forest dominated by *Myristica insipida*. In the Northern Territory, it grows in monsoon forests, often near the coast, forming vegetative colonies.

Phenology: Flowers January–February in the Kimberley, October–April elsewhere.

Affinities: The only other Australian species that remains in *Habenaria s. str*. is *H. maccraithii* Lavarack, which differs in its bright green leaves, brownish flowers and petals with two similar, slender lobes.

Notes: Known as the smelly socks orchid as the flowers develop an unpleasant odour which grows stronger during the day.

Common names: Coastal rein orchid, Smelly socks orchid.

Nervilia Comm. ex Gaudich. in Freycinet, *Voy. Uranie* 4: 5, t. 35 ([13 June] 1827) & 421 ([18 Sep.] 1829), *nom. cons*. *Type*: *N. aragoana* Gaudich., *type cons*.

Stellorkis Thouars, *Nouv. Bull. Sci. Soc. Philom. Paris* 1: 317 (1809), *nom. rej. Type*: *Arethusa simplex* Thouars *nom. rej.* vs. *Nervilia* Comm. ex Gaudich. (1829), *nom. cons.*

Cordyla Blume, *Bijdr. Fl. Ned. Ind.*: 416 (1825), *nom. illeg.*, *non* Lour. (1790). *Type*: not designated

Aplostellis A.Rich., *Mém. Soc. Hist. Nat. Paris* 4: 36 (1828); *Haplostellis* Endl., *Gen. Pl.*: 219 (1837), *orth. var*. *Type*: *A. ambigua* A.Rich., *nom. illeg.* (*Arethusa simplex* Thouars) ≡ *Stellorkis* Thouars (1809).

Roptrostemon Blume, *Fl. Javae, Praef.*: vi (1828); *Rophostemon* Endl., *Gen. Pl.*: 216 (1837), *orth. var*. *Type*: not designated (substitute name for *Cordyla* Blume).

Bolborchis Zoll. & Moritzi in A.Moritzi, *Syst. Verz. Java*: 89 (1846). *Type*: *B. crociformis* Zoll. & Moritzi.

Nervilia holochila (F.Muell.) Schltr., *Bot. Jahrb. Syst*. 39: 48 (1907); *Pogonia holochila* F.Muell., *Fragm*. 5: 200 (1866). *Type*: Queensland: 'Ad sinum Rockingham's Bay', 4 Dec. 1865, *J.Dallachy s.n*. (holo: MEL 677533; iso: K 000942700, MO 3343587).

Illustrations: Nicholls, *Orchids Austr.* 76, t. 284 (1969); D.L.Jones, *Native Orchids Austr.* 419, fig. (1988); J.Brock, *Top End Native Pl.* 265, pl. (1988); Dockr., *Austr. Indig. Orchids* 1 (edn. 2): 246, fig. p. 247 (1992); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1012, fig. 303i (1992); D.L.Jones, *Compl. Guide Austr. Orchids* 282, pl. (2006); A.P.Brown *et al*., *Orchids West. Austr.*, pls p. 398, 401 (2008); A.P.Brown *et al*., *Field Guide Orchids West. Austr.*, pls p. 475, 500, 501 (2013); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 646 pl. (2021).

Erect, terrestrial, geophytic *herb* to 35 cm, forming clonal colonies, tubers 12–30 mm diam. *Leaves* solitary, developing post-anthesis or independent of anthesis; petiole 20–60 mm long; lamina erect, 50–180 mm long, 40–80 mm wide, pale green, ovate to broadly ovate, strongly plicate, commonly with 7 prominent veins, glabrous, apex acute. *Inflorescence* a terminal raceme, fleshy, 15–25 cm high, elongating in fruit, with large sheathing bract below flowers. *Flowers* (1–)3–6, resupinate, lax, widely spreading, fragrant, tepals mauve, pink. cream or pale green, short-lived; pedicels 6–8 mm long. *Perianth*: sepals linear to lanceolate or narrowly obovate, 15–26 mm long, 3–4.5 mm wide, acuminate; petals 13–22 mm long, 3.5–5.5 mm wide, less acuminate than sepals; labellum 3-lobed, concave, 14–25 mm long, 12–18 mm wide when flattened, usually white at the base, grading to pink at the apex sometimes entirely pink or white, lateral lobes more or less erect and encircling the whole column, or oblong or rounded, 12–16 mm long, midlobe almost square to semicircular, 4–6 mm long, 5–7 mm wide, margins undulate, keel a raised, linear to oblong, hirsute ridge extending almost the entire length of the labellum. *Column*

erect, 10–12 mm long, dilated and very shortly winged at apex, with a hump behind the anther. *Anther* with a small bifid rostrum. *Pollinia* shallowly grooved. *Stigma* semicircular. *Capsule* pendulous, dehiscent. (Figure 16).

Fig. 16. *Nervilia holochila*. A, B. Pleated leaves. C, D. Inflorescence. E–G. Flowers. Vouchers: A, B: *R.L.Barrett* & *M.D.Barrett RLB 3190* (PERTH); C: *R.L.Barrett & M.D.Barrett RLB 949* (PERTH); D–G: not vouchered, from near Charnley River Station homestead. Photos by R.L. Barrett (A–C) & R. Maher (D–G).

Specimens examined: WESTERN AUSTRALIA: N side of wide gorge on S arm of Bachsten Creek, S border of Prince Regent River Reserve, 1 Feb. 1999, *M.D.Barrett & K.W. Dixon MDB 705* (PERTH); Gwen's Gorge, Edkins Ra., 6 Dec. 1994, *R.L.Barrett* & *M.D.Barrett RLB 949* (PERTH); beside small basalt hill, 2 km SW of Mount Fyfe, 04 Jan. 2001, *R.L.Barrett & M.D.Barrett RLB 1535A* (PERTH); *c.* 8.5 km NE of Mount Agnes, 6 Jan. 2001, *R.L.Barrett & M. O'Connor RLB 1573* (CANB, PERTH); Theda Station, *c.* 2 km S of homestead beside Kalumburu Road, 19 Feb. 2006, *R.L.Barrett* & *M.D.Barrett RLB 3190* (PERTH); Mission Station, Napier Broome Bay, 10 Dec. 1904, *G.F.Hill 21* (PERTH). NORTHERN TERRITORY: Kakadu National Park, Ranger Uranium Lease, 22 Apr. 1991, *K.Brennan 1418* (DNA); Berry Springs, *c.* 60 km S of Darwin, 24 Jan. 1978, *M.A.Clements 1044* (CANB); near Mt Howship, East Alligator River area, Arnhem Land, 18 Feb. 1984, *D.L.Jones 1438* (DNA); 15 km N Gray's Bay, NE Arnhem Land, 28 Feb. 1988, *D.Lucas & J.Russell-Smith 5076* (DNA). QUEENSLAND: Thursday Island, 1989, *J.R.Clarkson 7745* (CBG); near Port Curtis, 1981, *P.D.Hind 2893* (NSW); Thursday Island, hill near hospital, Feb. 1989, *D.L.Jones 3702* (CBG, NSW); Keats Island, 1999, *B.S.Wannan 1463* (NSW).

Distribution: North Kimberley, from Beverley Springs Station homestead, Prince Regent River, Mount Fyfe, Mitchell Plateau and Theda Station, also occurs in the Northern Territory, Queensland and Papua New Guinea.

Conservation status: Rarely seen in flower due to the brief flowering period (*c.* 1 week) and scattered occurrence, however the species is relatively widespread and not under immediate overall threat. Frequent fire may, however, be threatening some individual populations due to destruction of vine thicket habitats that maintain vital leaf litter and soil moisture levels.

Ecology: Occurs in a variety of habitats, usually in dark, peaty soils, from open Eucalypt woodland dominated by *Eucalyptus miniata, E. obconica* and *E. tetrodonta* with *Murdannia nudiflora*, *Premna herbacea*, *Sorghum* sp. to dense vine thicket with *Antidesma ghaesembila*, *Dioscorea bulbifera*, *Dipodium ammolithum* and *Ficus virens*.

It appears that clonal populations may persist for some time in habitats which are not their preferred ecological niche. In several instances, populations have been observed in relatively open woodland, usually beside creeks. Jones (2021) also reports this species from swamp margins. It is possible that minor recruitment can occur into open woodland, however the potential for successful sexual reproduction and long-term persistence of such populations is unknown.

Phenology: Flowers November–December.

Affinities: Perhaps closest to *N. aragoana* Gaudich., differing from it and all other Australian species in having ovate rather than cordate, circular or peltate leaves.

Notes: A rarely collected species in Western Australia, only one flowering specimen, collected in 1904, was known until December 1994 when it was found flowering in the Edkins Range, on the Mitchell Plateau and on Theda Station and more recently beside Beverley Springs (Charnley River) Station Homestead (R. Maher pers. comm.). In the Edkins Range, one gorge supports three large and several small colonies on rainforest slopes, the largest of which contains over five hundred plants, most of which are probably clonal. Flowering occurs soon after the first heavy wet-season rains.

Common name: Ribbed shield orchid.

Pecteilis Raf., *Fl. Tellur.* 2: 37 (1836 [1837]). *Lectotype*: *P. susannae* (L.) Raf., designated by Schlechter, *Repert. Sp. Nov. Regni Veg.* 4: 120 (1919).

Synmeria Nimmo in J.Graham, *Cat. Pl. Bombay, Add.*: s.p. (1839). *Type*: *S. schizochilus* Nimmo.

Centrochilus Schauer, *Nov. Actorum Acad. Caes. Leop.-Carol. Nat. Cur.* 19(Suppl. 1): 435 (1843). *Type*: *C. gracilis* Schauer.

Kraenzlinorchis Szlach., *Orchidee* (*Hamburg*) 55: 57 (2004). *Type*: *Kraenzlinorchis mandersii* (Collett & Hemsl.) Szlach.

Smithanthe Szlach. & Marg., *Orchidee* (*Hamburg*) 55: 172 (2004). *Type*: *Smithanthe rhodocheila* (Hance) Szlach. & Marg.

Plantaginorchis Szlach., *Richardiana* 4: 61 (2004). *Type*: *P. plantaginea* (Lindl.) Szlach.

[*Fimbrorchis* Szlach., *Orchidee* (*Hamburg*) 55: 489 (2004), *p.p.* as to *Pecteilis medioflexa* (Turrill) M.A.Clem. & D.L.Jones.]

Pecteilis elongata (R.Br.) M.A.Clem. & D.L.Jones, *Austral. Orchid Review* 83(6): 51 (2018); *Habenaria elongata* R.Br., *Prodr.* 313 (1810).

Lectotype: Northern Territory: Arnhem South [Caledon] Bay, Point U1, 6 Feb. 1803, *R.Brown* [*Bennett* No. 5540] (lecto: BM 000032259, designated by M.A.Clements, *Austr. Orchid Res.* 1: 85 (1989); isolecto: BM 000032260, E 00373992, ?E 00373993, ?K-LINDL K000061930, K 000827069, ?K 000827070).

Residual syntypes: Carpentaria, 1802/3, *R.Brown s.n.* (syn: AMES, K 000827068).

Habenaria millari F.M.Bailey, *Bot. Bull. Dept. Agric. Queensl.* 3: 18 (1891). *Type*: Queensland: Walsh River, *T.Barclay-Millar* (holo: BRI AQ0279604).

Habenaria triplonema Schltr., *Repert. Sp. Nov. Regni Veg.* 9: 435 (1911); *Pecteilis triplonema* (Schltr.) M.A.Clem. & D.L.Jones, *Austral. Orchid Review* 83(6): 51 (2018). *Type*: Northern Territory: Near Port Darwin, 1889, *M.Holtze* 979 (holo: B†; iso: MEL 108319).

Illustrations: Lavarack & B.Gray, *Trop. Orchids Austr.* pl. 10 & 12 (1985), as *H. triplonema*; D.L.Jones, *Native Orchids Austr.* 340, fig. (1988), as *H. triplonema*; Dockr. *Austr. Indig. Orchids* 1 (edn. 2): 218, 220, figs (1992), as both *P. elongata* and *P. triplonema*; A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1011, fig. 303g (1992), as *H. elongata*; Mabb. & D.T.Moore, *Bull. Nat. Hist. Mus. London, Bot. ser.* 190, pl. (1999), as *H. elongata*; D.L.Jones,

Compl. Guide Austr. Orchids (edn 2); 341, 344, pls (2006), as both *P. elongata* and *P. triplonema*; A.P.Brown *et al. Orchids West. Austr.,* pls p. 390, 393 (2008), as *H. triplonema*; A.P.Brown *et al.*, *Field Guide Orchids West. Austr.,* pls p. 473, 494 (2013), as *H. elongata*; D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 609 pl., fig. (2021), as both *P. elongata* and *P. triplonema*.

Erect geophytic *herb*, 30–80 cm tall, slender or moderately robust. *Leaves* 2–6, basal or one may be low down on the stem, 60–120(–150) mm long, 5–15(–20) mm wide, narrowly ovate to obovate, acute, often canaliculate, glabrous. *Inflorescence* a raceme of 10–25(–40) flowers, each flower subtended by a bract 5–7 mm long, tapered to a fine point; a few larger bracts on the rachis below the first flower, up to 24 mm long. *Pedicels* 2–5 mm long. *Ovaries* 10–14 mm long at anthesis, straight to slightly curved. *Flowers* white or cream; dorsal sepal and petals forming an erect galea; dorsal sepal 4–6 mm long, 3–4 mm wide, ovate, obtuse; lateral sepals spreading, 5–7 mm long, 2.5–3 mm wide, narrowly ovate and curved, acute; petals when flattened 5–7 mm long, 2.5–3 mm wide, falcate-triangular, obtuse, often with a small tooth-like lobe near the base of the anterior margin; labellum with three long, filiform lobes, the lateral lobes curved or twisted, usually asymmetrical, 15–25 mm long, the central lobe straight, 5–8 mm long, spur 20–35 mm long, 0.5–1.5 mm diam., dilated in the distal third, curved or even curled; column *c.* 1.5 mm long, auricles claviform, *c.* 0.5 mm long; anther thecae widely separated, parallel, thecal tubes one-third to as long as, but much more slender than the stigmatophores; stigmatophores *c.* 3 mm long, subcylindrical. *Capsule* 14–18 mm long, *c.* 3 mm wide. (Figure 17).

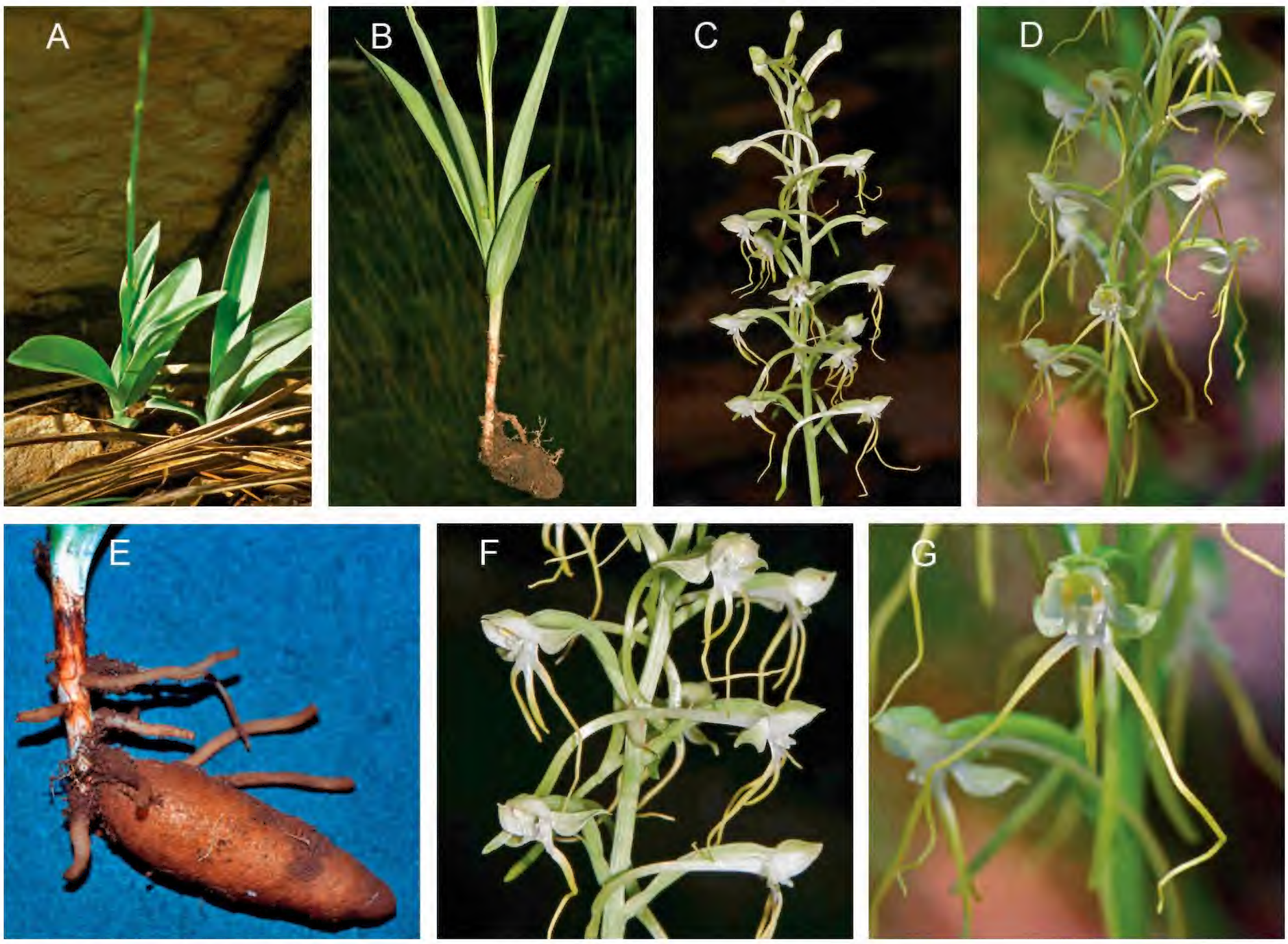

Fig. 17. *Pecteilis elongata*. A. Habit. B. Leaves and tuber. C, D. Inflorescence. E. Fleshy roots and tuber. F, G. Flowers. Vouchers: A, D, E, G: *R.L.Barrett RLB 1751* (PERTH); B, C, F: *R.L.Barrett, M.D.Barrett & M.Maier RLB 6489* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Specimens examined: WESTERN AUSTRALIA: 5 km due E of junction of Pitta Creek and Prince Regent River, 11 Jan. 2001, *M.D.Barrett & R.L. Barrett MDB 1193* (PERTH); 5.2 km SW of junction of Pitta Creek and Prince Regent River, 28 Jan. 2007, *M.D.Barrett & R.L.Barrett MDB 1836* (PERTH); Edkins Range, on Walcott Inlet track, 80 km N of Beverley Springs Station Homestead, 26 Dec. 1995, *R.L.Barrett & M.D.Barrett RLB 646* (PERTH); Synnot Ra., 25 km NW of Beverley Springs Stn Hstd, 14 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 709* (PERTH); cultivated at Beverley Springs Stn Hstd ex Edkins Ra., 80 km N of Beverley Springs Stn Hstd, 24 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 743* (PERTH); cultivated at Beverley Springs Stn Hstd ex

Edkins Ra., 63 km N of Beverley Springs Stn Hstd, 4 Feb. 1996, *R.L.Barrett* & *M.D.Barrett RLB 795* (PERTH); 'Leptospermum Falls', Prince Regent River Reserve, 10 Jan. 2001, *R.L.Barrett* & *M.D.Barrett RLB 1699* (CANB, PERTH); 3 km SW of Mount Fyfe, 11 Jan. 2001, *R.L.Barrett RLB 1751* (CANB, PERTH); 2 km S of Bachsten Creek Camp, in Edkins Range, 26 Jan. 2010, *R.L.Barrett, M.D.Barrett & M.Maier RLB 6489* (PERTH); 15 km S of Mitchell River Station Road turn-off, from King Edward [River], Mitchell Plateau Road, Mitchell Plateau, NW Kimberley, 07 Feb. 1979, *K.F.Kenneally 7071* (PERTH); Mitchell Plateau Mining Camp, 17 Jan. 1979, *J.Smith s.n.* (PERTH). NORTHERN TERRITORY: Kapalga; Kakadu National Park, 25 Jan. 1994, *J.Egan 3057* (DNA); Port Darwin, *n.d.* [?1889], *M.W.Holtze 1058* (MEL); Kapalga gate dividing buffalo and non-buffalo plots, 15 Feb. 1984, *D.L.Jones 1415* (DNA); 2 km W of Bankas Jungle, 10 Mar. 1994, *S.Taylor 162* (DNA); Milingimbi; Arnhem Land, 19 Mar. 1987, *G.M.Wightman 3509* (CANB, DNA). QUEENSLAND: near Bamaga, 1986, *B.Gray 4291* (CANB); Fly Point, Albany Passage, northern end of Newcastle Bay, Cape York Peninsula, 15 Feb. 1986, *D.L.Jones 2300* (CANB); Moa Island, *c.* 1 km NW of Kubin, near airstrip, 14 Feb. 1989, *D.L.Jones 3623* (CBG, NSW); Moa Island, *c.* 1 km NW of Kubin, near airstrip, 15 Feb. 1989, *D.L.Jones 3641* (CBG).

Distribution: North Kimberley, from the Synnot Range, north to the Mitchell Plateau and Theda Station, east to the north-west Northern Territory, Walsh River in Queensland and recorded in the Western Province of Papua New Guinea by Renz (1987) and Kolanowska *et al.* (2021).

Conservation status: Relatively widespread, and relatively common in the Prince Regent National Park. Not considered threatened.

Ecology: Occurs on shallow sand amongst sandstone with *Triodia* spp., recorded with *Corymbia torta* ssp. *torta*, *Corymbia* ?*greeniana*, *Cymbopogon procerus*, *Eucalyptus tetrodonta*, *Gardenia* spp., *Goodenia sepalosa*, *Terminalia canescens*, *T. ferdinandiana*. Usually in dryer locations than other terrestrial orchids in the Kimberley.

Phenology: Flowers January–February.

Affinities: Probably most closely allied to *P. mutica* (Span.) M.A.Clem. & D.L.Jones, which has narrow, erect leaves and very thin lateral labellum lobes, and *P. leptophylla* (Renz) M.A.Clem. & D.L.Jones, which also has narrow, grass-like leaves.

Notes: Original collections of *Habenaria elongata* were made by Brown at five different locations in the Gulf of Carpentaria (Mabberley & Moore 2022), but it is not always possible to link duplicates to particular locations, so some duplicates are listed above with '?' as they may be syntypes for other locations.

There has been long-standing confusion as to the putative differences between *Pecteilis elongata* and *P. triplonema*. Each author treating these two taxa provides differing, subtle characters on which to separate them, but the differences observed may only be regional variation within a single taxon. Dockrill (1969) considered *P. elongata* to have lateral labellum lobes of unequal length, equal in *P. triplonema*. This character is variable for *P. elongata*, notably, the lobes on the type specimen being equal in length. Renz (1987) studied material of *P. elongata* from New Guinea, and in examining descriptions of *P. triplonema*, considered it likely that the two names were conspecific. Wilson (1992) noted that *P. elongata* was very similar to *P. triplonema*, but gave no differences between the taxa. Jones (2002) considered *P. elongata* and *P. triplonema* to be distinguishable based on flower colour and twisting of the lateral lobes of the labellum. Jones (2006) considered the lateral lobes of the labellum to diverge at different angles from the midlobe, 50–80° for *P. elongata* and 30–40° for *P. triplonema*, but these differences are not consistent between populations assigned to either taxon. Jones (2021) provides comparative illustrations which highlight potential differences in the length of the lateral lobes of the labellum, and in the shape of the column, raising the possibility that a second entity should be recognised.

Examination of the original description of *P. triplonema* by Schlechter (1911) showed that he did not compare his new species with *P. elongata* directly, rather with the Indonesian species *P. mutica* Span. Given that the holotype of *P. triplonema* was destroyed, previous authors have been unable to determine if there are reliable differences between these two taxa. There are a large number of Schlechter duplicates extant at NSW (Blaxell 1973), but no material of *P. triplonema* has been found there. Christenson (1987) has documented Schlechter material at PR and S. Steudel *et al.* (2012) recently identified a large number of duplicates of Schlechter Orchidaceae type specimens at Z and ZT that had not previously been recognised as isotypes, but duplicates of *P. triplonema* were not found. However, authentic isotype material has recently been recognised at MEL and after examination of this specimen we here consider *P. triplonema* to be a synonym of *P. elongata*. Further study of variation in this taxon, and the application of the name *Habenaria millari* F.M.Bailey is encouraged.

Common names: White rein orchid, Twisted rein orchid, Three-lobed butterfly orchid.

Pecteilis eurystoma (Schltr.) M.A.Clem. & D.L.Jones, *Austral. Orchid Review* 83(6): 51 (2018); *Habenaria eurystoma* Schltr., *Repert. Spec. Nov. Reg. Veg. Beih.* 10: 248 (1912). *Lectotype*: Queensland: Newcastle Range, 1875, *W.E. de M.Armit* 390 (syn: B†; lecto: MEL 108303), designated by M.A.Clements, *Austr. Orchid Res.* 1: 86 (1989).

Residual syntype: Northern Territory: Port Darwin, 1886, *M.Holtze* 651 (syn: B†; MEL 108304).

Habenaria praecox Lavarack & Dockrill, *Austrobaileya* 5(2): 331, f. 1 (1999); *Pecteilis praecox* (Lavarack & Dockrill) M.A.Clem. & D.L.Jones, *Austral. Orchid Review* 83(6): 51 (2018). *Type*: Queensland. North Kennedy District: about 12 km south of Cardwell, 18 23'S, 146 05'E, 6 Feb. 1997, *P.S.Lavarack PSL 4001* (holo: BRI-AQ0716327; iso: CANB 523191, NSW 503587).

Habenaria halata D.L.Jones, *The Orchadian* 13: 518 (2002); D.L.Jones, *Compl. Guide Austr. Orchids* 342, pl. (2006); *Pecteilis halata* (D.L.Jones) D.L.Jones, *Austral. Orchid Review* 84(1): 19 (2019). *Type*: Northern Territory: Yarrawonga Swamp, 20 km E of Darwin, 15 Dec. 1984, *D.L.Jones 1740* (holo: DNA D0025719).

Habenaria sp. Beverley Springs Station (M.D. Barrett MDB 185), Western Australian Herbarium. (1998–). FloraBase – The Western Australian Flora. Department of Environment and Conservation. http://florabase.dpaw.wa.gov.au/ [accessed 14 August 2012].

Habenaria ochroleuca auct. non R.Br.: Dockrill, *Austr. Indig. Orchids* (edn. 1); 1: 38, pl. 28 (1969), *p.p.* as to Kimberley.

Habenaria joesmithii K.W.Dixon, R.L.Barrett & M.D.Barrett in A.P.Brown *et al.*, *Field Guide Orchids West. Austr.,* pls p. 496–497 (2013), *nom. inval.*

Illustrations: A.P.Brown *et al. Orchids West. Austr.,* pl. p. 393 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.,* pls p. 494, 496, 497 (2013), both as *H. joesmithii* ms; ?Liddle *et al.*, *Field Guide Pl. Darwin Sandsheet Heath* [27], pl. (2017).

Tuberous terrestrial *herb* growing in loose groups. *Tubers* broadly ovoid, 3.5–4.6 cm long, 1–2.2 cm wide, fleshy. *Leaves* obliquely erect, 3 or 4, radical, blade flat to somewhat conduplicate or canaliculate, linear-lanceolate, 2.5–11(–15) cm long (short at anthesis, elongating with age), 6–11(–18) mm wide, dark to dull green, acute to apiculate. *Inflorescence* 12–39 cm tall, slender, *c.* 4 mm diam. near base, *c.* 2.7 mm diam. below the first flower, smooth until just below flowers when becoming ribbed, 11–30-flowered; sterile bracts 3–9, lanceolate, 3.5–14(–23) mm long, 1.5–2.4(–3.5) mm wide, sheathing at the base, long-acuminate; fertile bracts lanceolate, 3–13 mm long, 1–2.5 mm wide, base sheathing. *Pedicels* slender, *c.* 3 mm long, straight or slightly curved. *Ovary* linear to very narrowly ovate, becoming curved, 7–12.5(–21) mm long, 1–1.5(–2.4) mm wide, curved near the apex. *Flowers* 7–12 mm diam., white to very slightly greenish, sweetly fragrant in the morning, moderately spaced, 30–60% overlap between flowers. *Dorsal sepal* pale to dark green, erect, broadly ovate, 2.4–4.7 mm long, 1.8–4.0 mm wide, slightly cucullate, faintly 3-nerved. *Lateral sepals* widely divergent, ovate, 4–6 mm long, 1.7–2.2(–4.0) mm wide, slightly asymmetric to somewhat deltoid, faintly 3-nerved, apex acute. *Petals* erect, ovate to broadly ovate, 3.7–5.4 mm long, 1.7–3.2 mm wide, anterior margin near base with a shallow, rounded flange, apex shallowly acute. *Labellum* obliquely deflexed, 6.2–9.2 mm long, 10–19.1 mm wide when flattened, deeply trilobate; base 2.7–4.6 mm long, 2.2–3.8 mm wide; lateral lobes widely divergent, straight to curved upwards near the tips, narrowly linear, 4.5–9.1 mm long, 0.75–1.8 mm wide, distal margins slightly erose, apex obtuse; mid-lobe almost straight to slightly obliquely deflexed, very narrowly triangular, 4.0–6.9 mm long, 0.8–2.0 mm wide, margins slightly irregular, apex usually obtuse. *Spur* shallowly recurved in distal half, 7.9–9.3(–10.3) mm long, 1.8–2.1 mm wide near mouth, gradually tapering to a constriction 1.0–1.1 mm wide, then expanding to a maximum width of 1.8 mm near tip, slightly curved; throat inside diam. 1.3–1.6 mm. *Column* bluntly porrect, 1.8–2.7 mm long, 2.0–2.5 mm wide, 1.3–1.9 mm thick; auricles linear-cylindrical, *c.* 2.1 mm long, obtuse; stigmatophores cylindrical, 0.8–1.5 mm long. *Anthers* 1.1-1.3 mm long, *c.* 0.6 mm wide, oblong, yellow turning spotted brown in age, apex acute, the anther sacs widely separated; anther channels clavate, 0.3–0.5 mm long. *Rostellum* vestigial. *Pollinia* narrowly ovoid, *c.* 1.2 mm long, 0.7 mm wide, yellow, sectile; pollinia stalks *c.* 0.5 mm long, cream, attachment pads *c.* 0.3 mm across. *Capsules* erect, narrowly obovoid, 9.4–12.9(–21) mm long, 2.0–4.2 mm wide. (Figure 18)

Fig. 18. *Pecteilis eurystoma*. A, B. Habit. C. Leaves, roots and tuber. D. Leaves. E, F. Inflorescence. G–J. Flowers. Vouchers: A–C: *R.L.Barrett & K.W.Dixon RLB 1648* (PERTH); (D–K): not vouchered, cultivated at Kings Park & Botanic Garden, from Edkins Range. Photos by R.L. Barrett & M.D. Barrett.

Diagnostic characters: Differs from *P. ochroleuca* in the forward-projecting lateral labellum lobes. Differs from *P. vatia* in the lateral labellum lobes not recurved towards the apex.

Specimens examined: WESTERN AUSTRALIA: 0.5 km NW of Beverley Springs Station Homestead, W Kimberley, 10 Feb. 1993, *M.D.Barrett 185* (PERTH); Theda Station access gate, SE of homestead, north Kimberley region, 15 January 2016, *M.D.Barrett MDB 4918* (PERTH); *c.* 5 km SW of Mt Fyfe, Drysdale River Station 30 Jan. 2000, *M.D.Barrett & K.W.Dixon MDB 983* (PERTH); 3.5 km NW of Mt Agnes, near Prince Regent River, 9 Jan. 2001, *M.D.Barrett 1172* (PERTH); 18.8 km WNW of Munja Airstrip, Harding Range plateau, Harding Range, N of Walcott Inlet, W Kimberley, 19 Jan. 2007, *M.D.Barrett & R.L.Barrett MDB 1799* (CANB, PERTH); beside Long Creek, 15 km NW of Beverley Springs Stn Hstd, 7 Jan. 1996, *R.L.Barrett & M.D.Barrett RLB 696* (PERTH!); Edkins Ra., 78 km NNW of Beverley Springs Stn Hstd, 11 Jan. 1995, *R.L.Barrett & M.D.Barrett RLB 955* (PERTH); *c.* 3 km SE of Mount Fyfe, 7 Jan. 2001, *R.L.Barrett & K.W.Dixon RLB 1632* (PERTH); *c.* 8 km N of Charnley River crossing on Walcott Inlet track, Edkins Range, 8 Jan. 2001, *R.L.Barrett & K.W.Dixon RLB 1648* (PERTH); Theda Station, *c.* 2 km SE of homestead S. of rubbish dump, beside Kalumburu Road, 21 Feb. 2006, *R.L.Barrett & M.D.Barrett RLB 3252* (PERTH); 'Isoetes Creek' (informal name), W of Quail Creek, 15.9 km SSE of Kings Cascades, Prince Regent River Reserve, 22 Jan. 2007, *R.L.Barrett & M.D.Barrett RLB 3760* (PERTH); Youwanjela pavement 1, 26.7 km E of Kings Cascades; 12.4 km

NNE of junction of Youwanjela Creek and Prince Regent River, Prince Regent Nature Reserve, 25 Jan. 2007, *R.L.Barrett & M.D.Barrett RLB 3842* (PERTH); Track S of Airfield, Mitchell Plateau, N Kimberley, 26 Jan. 1982, *K.F.Kenneally 7995* (PERTH 00250988); Airfield Swamp, Mitchell Plateau mining camp, 15 Jan. 1979, *J.Smith s.n.* (PERTH). NORTHERN TERRITORY: Arnhem land: *c.* 22 km NE of Oenpelli Mission, 17 Feb. 1973, *L.G.Adams 2994* (CANB); Kakadu National Park, Ranger Uranium Mine, 19 Dec. 1991, *K.Brennan 1705* (DNA); Cobourg Peninsula; N of track to Raffles Bay pearl farm, 1 Feb. 2005, *I.D.Cowie 10408* (CANB); Jabiru, swamp N airport, 11 Dec. 1984, *D.L.Jones 1715* (CANB, DNA); Djapididjapin about 12 miles [19 km] from Nangalala, 15 Jan. 1973, *H.Reeve 583* (CANB); Nhulunbuy, East Woody Beach, 12 Feb. 1988, *J.Russell-Smith 4704* (DNA). QUEENSLAND: Iron Range, 19 Dec. 1988, *L.Lawler 144* (CANB); McIlwraith Range, 1999, *B.S.Wannan & R.Jago 1110* (NSW).

Distribution: From Beverley Springs [Charnley River] Station, Mt Elizabeth Station, and Edkins Range, north to the Mitchell Plateau and Theda Station in the north Kimberley region of Western Australia. As broadly defined here, also in the top end of the Northern Territory, and far north Queensland.

Etymology: From the Latin *eurys* (broad) and *stoma* (mouth), in reference to the mouth of the spur.

Conservation status: Very common on seasonally wet sand flats over sandstone in the north-west Kimberley and not under threat.

Ecology: Occurs on sand flats over laterite and sandstone. Recorded in association with *Acacia nuperrima, Calochilus barbarossa*, *Calochilus kimberleyensis*, *Crinum uniflorum*, *Drosera* aff. *paradoxa*, *Empusa habenarina*, *Eucalyptus apodophylla*, *Eulophia bicallosa*, *Fimbristylis* spp., *Grevillea pteridifolia, Haemodorum brevicaule*, *H. flaviflorum*, *Pandanus darwinensis*, *P. spiralis*, *Stylidium prophyllum*, *S. rubriscapum*, *Utricularia chrysantha* and *Xyris complanata*.

Phenology: Flowers and fruits December–February.

Notes: In WA first recorded from the Mitchell Plateau (Dixon *et al.* 1989) and mentioned in Wilson (1992) as a form of *P. ochroleuca*, this species is now known from Theda and Doongan [King Edward River] Stations in the northern Kimberley, south to Beverley Springs Station in the north-west Kimberley. *Pecteilis eurystoma* is perhaps the most numerous orchid species in the Kimberley and individual sand flats can support thousands of plants in suitable habitats.

The first author has searched at B for any traces of the syntypes of *Habenaria eurystoma* and none could be located. A duplicate at MEL was designated as lectotype by Clements (1989).

Pecteilis eurystoma is here broadly defined to include *P. praecox* (Lavarack & Dockrill) M.A.Clem. & D.L.Jones (see Lavarack and Dockrill, 1999), *P. halata* (D.L.Jones) D.L.Jones and *Habenaria* sp. Beverley Springs Station (M.D. Barrett MDB 185). Jones (2021) maintained *P. eurystoma*, *P. halata* and *P. praecox* as distinct species, but if this status is justified, the distinction between each remains to be clearly defined. We remain open to the idea that some or all of these taxa represent distinct entities, especially given significantly disjunct distributions, however each is sufficiently morphologically variable that we have been unable to identify consistent morphological differences between them at present. Molecular data will likely be required to test species limits in this complex. *Pecteilis eurystoma* may also be related to *P. ochroleuca*. The description above is based entirely on WA material, so that any future changes to concepts will not necessitate re-description for this region.

The taxon illustrated by Renz (1987) as *Habenaria ochroleuca* is actually more closely allied to *P. propinquior*.

The flowers of this species are sweetly fragrant.

Common names. Western Butterfly orchid, Sweet Rein Orchid, Early rein orchid.

Pecteilis ochroleuca (R.Br.) M.A.Clem. & D.L.Jones, *Austral. Orchid Review* 83(6): 51 (2018); *Habenaria ochroleuca* R.Br., *Prodr.* 313 (1810). *Type*: Northern Territory: [Pobassoo] Island (Y2), [Arnhem Land], 18 Feb. 1803, *R.Brown* [*Bennett* No. 5539] (lecto: BM 000032261, designated by Clements, *Austral. Orchid. Res.* 1: 86 (1989); isolecto: K 000827061, K 000827062, K 000827063; K-LINDL 000061931).

Syntypes: North Coast, Islands Y1, Z1, Z2, Feb. 1803, *R.Brown s.n.* (syn: BM, K, L, *n.v.*).

Illustrations: D.L.Jones, *Native Orchids Austr.* 339, pl., fig. (1988); Dockr. *Austr. Indig. Orchids* 1 (edn. 2): 216, fig. p. 217 (1992); A.J.G.Wilson in J.R.Wheeler (ed.) *Fl. Kimb. Reg.* 1011, fig. 303h (1992); Mabb & D.T.Moore, *Bull. Nat. Hist. Mus. London, Bot. ser.* 190, pl. (1999); D.L.Jones, *Compl. Guide Austr. Orchids* 343, pl. (2006); A.P.Brown *et al.*, *Orchids West. Austr.*, pl. p. 393 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 496 (2013), all as *Habenaria ochroleuca*; D.L.Jones, *Compl. Guide Native Austr. Orchids* (edn 3); 607, pl., fig. (2021).

Erect, geophytic *herb* to 40 cm tall. *Leaves* 3 or 4, 1 or 2 near the base, reducing to sheathing bracts up the stem, oblong or ovate, 20–40 mm long, 12–20 mm wide, acute or acuminate. *Inflorescence* a raceme with 10–25 flowers. *Flowers* white, *c*. 10–14 mm diam., the dorsal sepal and labellum spur often green; pedicels up to 3 mm long. *Perianth*: dorsal sepal erect, 4–5 mm long, 3–4 mm wide, ovate; lateral sepals 4–5 mm long, *c*. 3 mm wide, falcate to narrowly ovate, widely spreading and upcurved; petals forming a galea with the dorsal sepal, 3–4 mm long, *c*. 2 mm wide, falcate-elliptical; labellum deeply 3-lobed and spurred; lateral lobes 7–8 mm long, *c*. 3 mm wide, narrowly falcate-triangular to narrow falcate-subovate, widely spreading and apical third curved up towards the dorsal sepal; midlobe recurved, 5.5–6 mm long, 0.7–1.0 mm wide, linear, obtuse; spur 10–15 mm long, 1.5–2 mm wide, contiguous with the ovary in the proximal third then curved forwards, dilated near apex. *Column c*. 2.5 mm high, auricles *c*. 1 mm long, erect, bluntly conical. *Anther* emarginate or truncate on top, anther locules parallel, 2.5–3 mm long, *c*. 1 mm apart; thecal tubes about 1.5–2 mm long; stigmatophores almost twice as long as the thecal tubes. *Capsule c*. 12 mm long, 4 mm wide. (Figure 19).

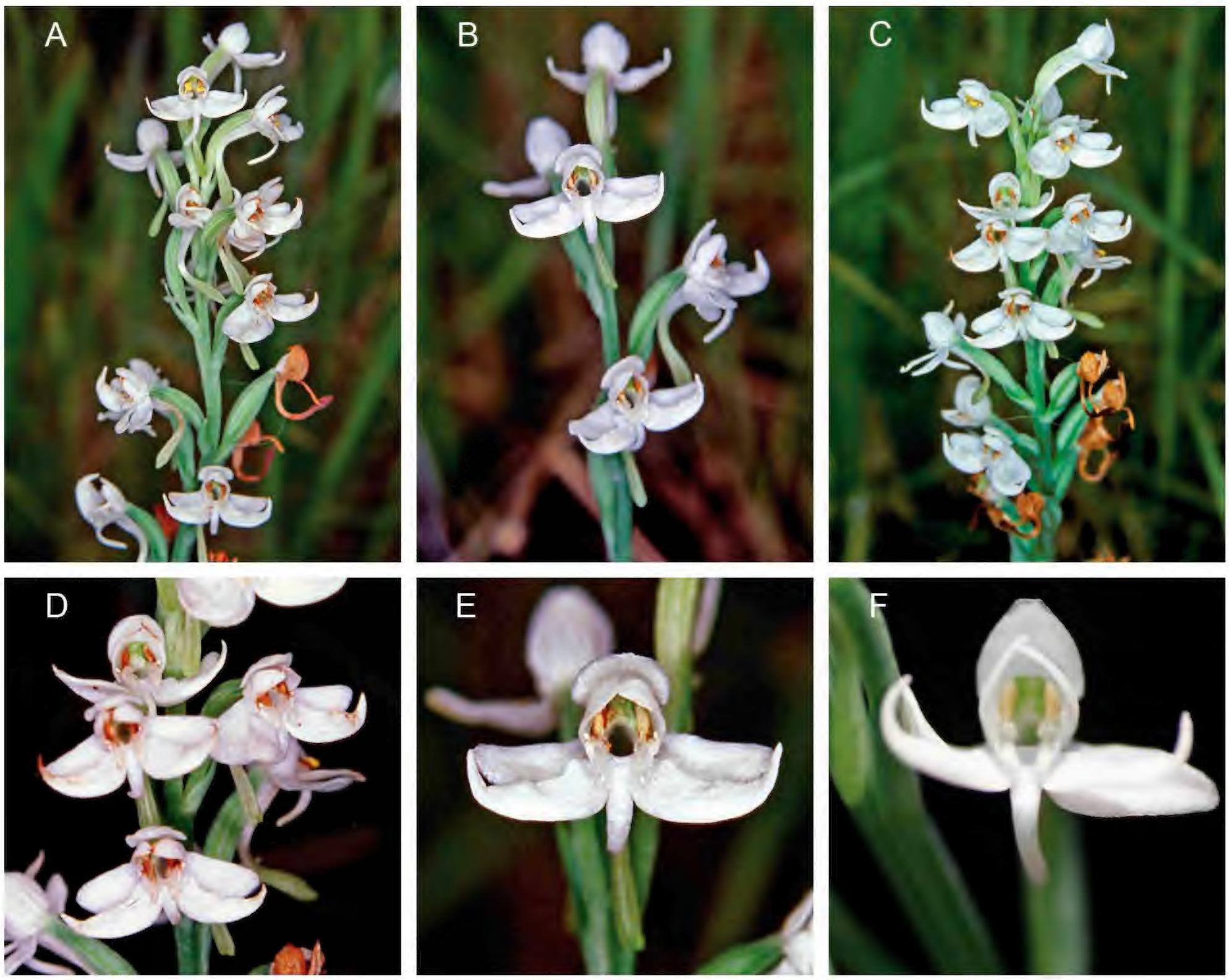

Fig. 19. *Pecteilis ochroleuca*. A–C. Inflorescence. D–F. Flowers. Vouchers: *R.L.Barrett & M.D.Barrett RLB 3209* (PERTH); F: *R.L.Barrett* & *M.D.Barrett RLB 742* (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Specimens examined: WESTERN AUSTRALIA: *c*. 1 km SE of Theda Station Homestead, 30 Jan. 2003, *M.D.Barrett MDB 1445* (PERTH); Theda Station access gate, SE of homestead, north Kimberley region, 15 Jan. 2016, *M.D.Barrett MDB 4919* (PERTH); Synnot Ra., 22 km NW of Beverley Springs Stn Hstd, 12 Mar. 1995, *R.L.Barrett RLB 1028* (PERTH); 0.5 km SSW of Beverley Springs Station Homestead, 05 Apr. 1995, *R.L.Barrett RLB 1069* (PERTH); 0.5 km SSW of Beverley Springs Stn Hstd, 23 Jan. 1996, *R.L.Barrett* & *M.D.Barrett RLB 742* (PERTH); Theda Station, homestead gate at N. end of airstrip, beside Kalumburu Road, 19 Feb. 2006, *R.L.Barrett* & *M.D.Barrett RLB 3209* (PERTH); 6.3 km ESE of old base camp site (Camp Creek Crossing) on Mitchell Plateau–King Edward River Road, 1.3 km N of road at base of low basaltic outcrop, Feb. 1986, *K.W.Dixon 680* (PERTH); Mitchell River, 22 Feb. 1980, *C.R.Dunlop 5232* (PERTH); Mitchell Plateau, near Amax Basecamp, 03 Feb. 1979, *K.F.Kenneally 6968* (CANB, K, PERTH); Adjacent to Amax Basecamp, Mitchell Plateau, 04 Feb. 1979, *K.F.Kenneally 6996* (PERTH). NORTHERN TERRITORY: Arnhem Land district: Elcho

Island: along road from Gali Winku township to mouth of Wurrmalmirr Creek, 4 Feb. 1978, *M.A.Clements 1165* (CBG); Cobourg Peninsula; just south of Danger Point, 30 Jan. 2005, *I.D.Cowie 10373* (CANB); *c.* 44 km directly ~NNW of Oenpelli, or *c.* 56 km by road, 15 Mar. 1973, *L.A.Craven 2271* (CANB); Angularli Creek, Murganella–Oenpelli Road, 9 Feb. 1984, *D.L.Jones 1359* (CANB); Latram River, NE Arnhem Land, 14 Feb. 1987, *G.M.Wightman 4161* (CANB, DNA).

Distribution: North west Kimberley, Mitchell Plateau, Theda, Doongan (King Edward River), Drysdale River and Charnley River (Beverley Springs) Stations and in the Northern Territory.

Conservation status: This species has a poorly known and scattered distribution, but it is relatively widespread and probably not under threat.

Ecology: Recorded from seasonally wet clay soils in association with *Dipodium basalticum*, *Erythrophleum* aff. *chlorostachys*, *Eucalyptus tectifica*, *Melaleuca minutifolia*, *Murdannia* aff. *graminea*, and *Terminalia canescens*.

Phenology: Flowers January–February(–April).

Affinities: Similar to *P. eurystoma* (including *P. halata* and *P. praecox*), each of which have previously been included in *P. ochroleuca*. *Pecteilis ochroleuca* differs in its lateral lobes being strongly reflexed, and having short, semi-cauline leaves.

Notes: While rarely seen in the Kimberley, it is not uncommon in suitable habitats and may be more widespread that current collections indicate.

Common names: Sickle orchid, Bent-lobed butterfly orchid, Moustache orchid.

Phoringopsis D.L.Jones & M.A.Clem., *The Orchadian* 13(10): 457 (2002). *Arthrochilus* subgen. *Phoringopsis* (D.L.Jones & M.A.Clem.) Szlach., *Richardiana* 3(2): 97 (2003). *Type*: *P. byrnesii* (Blaxell) D.L.Jones & M.A.Clem.

Notes: Since the inclusion of tropical species in *Arthrochilus* F.Muell. by Blaxell (1972), and the subsequent segregation of *Phoringopsis* D.L.Jones & M.A.Clem. and *Thynninorchis* D.L.Jones & M.A.Clem. (Jones *et al.* 2002) there has been debate about the recognition of these taxa at generic level, with Australian herbaria differing in their acceptance. The two species groups separated from *Arthrochilus s. str.* each have a set of morphological distinctions detailed by Jones *et al.* (2002; 2006). where *Phoringopsis* is distinguished from its nearest sister genus, *Arthrochilus* F.Muell., by 1 or 2 elongate, distichous basal leaves, inflorescence emerging with the leaves, smooth, non-papillate column foot and sepal bases, labellum attached basally (not via a peltate stalk), and the callus reduced-insectiform and ornamented with penicillate calli in *Phoringopsis*, compared to solitary leaves, inflorescences arising separately from leaves, attached by a peltate stalk, and labellum with an intricately insectiform callus. Miller & Clements (2014) confirmed that each genus was phylogenetically distinct and we therefore here follow the Australian Plant Census and maintain them as separate genera.

Phoringopsis byrnesii (Blaxell) D.L.Jones & M.A.Clem., *The Orchadian* 13(10): 457 (2002). *Arthrochilus byrnesii* Blaxell, *Contr. New South Wales Natl. Herb.* 4: 278–279, pl. 25, fig. D1–2 (1972). *Type*: Northern Territory: Waterfall Creek, South Alligator R., 2 April 1969, *N.Byrnes 1530* (holo: NSW 88430; iso: DNA D0002669*; NT D0002669*).

Illustrations: A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 354, 357 (2008); A.P.Brown *et al.*, *Field Guide Orchids West. Austr.*, pls p. 475–477 (2013), both as *Arthrochilus byrnesii*.

Plants terrestrial, tuberous, solitary or growing in small clusters, possibly clonal. *Leaves* 2–3, radical, one much longer than others; the largest leaf linear-lanceolate, to 25 cm long, 8–15 mm broad, narrowed tapered to the base, enclosing the peduncle, mid-green. *Inflorescence* many-flowered, 10–50 cm long, usually exceeding the leaves. *Flowers* widely spaced, lowermost about halfway along the peduncle. *Inflorescence* bract central on peduncle, *c.* 7 mm long, 3 mm wide, ovate-lanceolate, sheathing. Floral bracts similar to inflorescence bract. *Flowers* greenish, 12–20 mm long, on slender pedicels *c.* 5 mm long (excluding ovary). *Ovary* 5 mm long at anthesis. *Dorsal sepal* narrowly spathulate, margins incurved, not enclosing the column, 8–10 mm long, 2.5–3 mm wide. *Lateral sepals* obtuse, falcate, triangular, 6–8 mm long, 1.5–2.5 mm wide. *Petals* 6–9 mm long, 0.5–1.5 mm wide, linear, slightly falcate, obtuse. *Labellum* hinged on foot of column with a short claw, ovate-lanceolate, lamina apex notched; lamina 5–7 mm long, 2.0–2.5 mm wide; top of labellum with a large mushroom-shaped callus *c.* 2 mm high, 2 mm wide, densely covered with hair-like processes, 0.5–1.0 mm long, the apices minutely hairy, a few processes also scattered on the lamina towards the claw. *Callus head* with a sigmoid appendage 2–3 mm long, apex bifid, covered in hair-like processes and warty protuberances, projecting towards the base of the column. *Column* curved, slightly shorter than the dorsal sepal, its base almost at right angles to the ovary and prolonged to form a column "foot" 3 mm long, flattened dorsiventrally

and also at right angles to the ovary. Two pairs of "wings" or auricles are present, the larger pair attached on the sides of the dorsiventrally flattened column about halfway between the ovary and stigma, falcate-triangular, 4 mm long, 1 mm wide at the base which is decurrent on the edge of the column; the smaller pair of auricles attached behind the anther, triangular, 0.5–1 mm long. *Anther* terminal on column. *Stigma* below the anther, cup-shaped, 1–1.5 mm wide, margins crenulate. *Pollinia* 4 clavate, flat, mealy, yellow. *Capsule* glabrous, erect, 8–12.5 mm long, 3–5.5 mm wide. (Figure 20).

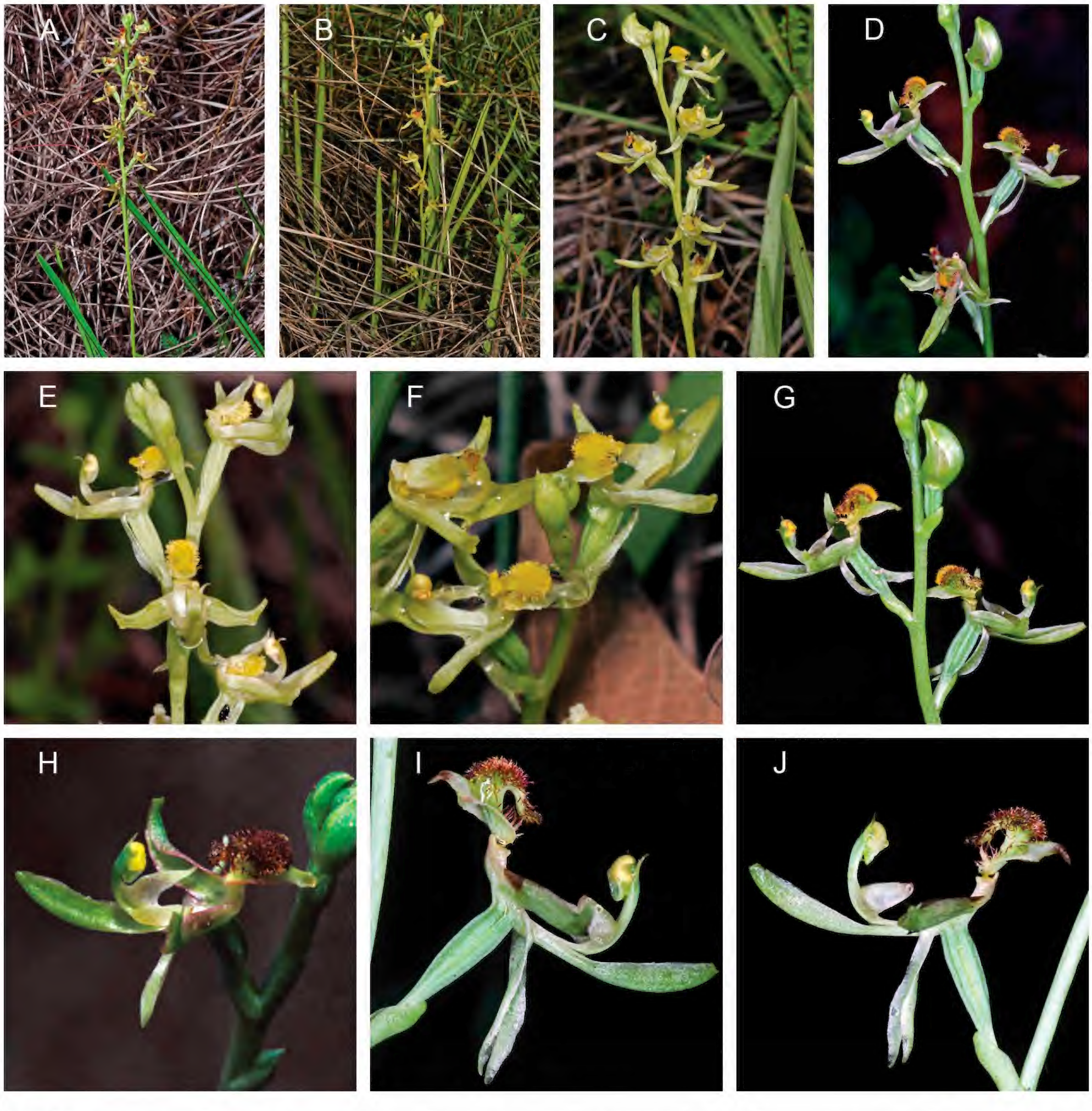

Fig. 20. *Phoringopsis byrnesii*. A, B. Habit and habitat in *Triodia* clumps. C–G. Inflorescences. H–J. Flowers. Vouchers: A–C, E, F: *R.L.Barrett & M.D.Barrett RLB 4025* (PERTH); D, G, I, J: *R.L.Barrett* & *M.D.Barrett RLB 1715* (PERTH); H: *M.D.Barrett* 859 (PERTH). Photos by R.L. Barrett & M.D. Barrett.

Specimens examined: WESTERN AUSTRALIA: 200 m E of summit of Mount Bomford, Drysdale River Station, 25 Jan. 2000, *M.D.Barrett* 859 (PERTH 06347819); 1.2 km E of summit of Mount Bomford, Drysdale Station, 30 Jan. 2000, *M.D.Barrett 991* (PERTH 06347827); edge of Plateau above upper Prince Regent River, 3.5 km E of Mount Agnes, 2 Feb. 2000, *M.D.Barrett 1037* (PERTH 06348696); above narrow gorge off S side of upper Prince Regent River, 4 km NE of N of Mount Agnes, 2 Feb. 2000, *M.D.Barrett 1051* (PERTH 06347835); on massive sheeting sandstone beside Morgan River near Cypress Valley, 2.7 km SE of Theda Station homestead, 23 Feb. 2005, *M.D.Barrett MDB 1694* (PERTH); sandstone pavement, 6.5 km NE of junction of Pitta Creek and Prince Regent River, W of Reserve boundary, 10 Jan. 2001, *R.L.Barrett* & *M.D.Barrett RLB 1715* (PERTH 08042284); sandstone pavement near the headwaters of the Prince Regent River, E of reserve, 21 Jan. 2003,

R.L.Barrett & *M.D.Barrett RLB 2617* (PERTH 08042527); 6.5 km NE of junction of Pitta Creek and Prince Regent River, just outside (E of) Prince Regent Nature Reserve, 28 Jan. 2007, *R.L.Barrett* & *M.D.Barrett RLB 4025* (CANB; PERTH 08042292); sandstone pavement (MP1-2010), Mitchell Plateau, 5 km NW of Surveyors Falls, 24 Jan. 2010, *R.L.Barrett & M.D.Barrett RLB 6408* (PERTH); sandstone pavement on W side of King Edward River, WNW of Theda Station Homestead, 12 Mar. 2014, *R.L.Barrett RLB 8969* (PERTH). NORTHERN TERRITORY: Bradshaw Station, mouth of Victoria River, 6 Apr. 2002, *I.Morris ORG3984* (CANB); upper East Alligator River area, Arnhem Land, 20 Feb. 1991, *J.Russell-Smith 8437* (CANB); Mitmiluk National Park; eastern edge of Marrawal Plateau, 7 Feb. 1996, *J.Russell-Smith 10510* (CANB).

Distribution: In Western Australia, disjunct populations occur from the Prince Regent River north to Theda Station in the north Kimberley region. Also known from disjunct populations on Bradshaw Station and the South Alligator River region of Kakadu National Park in the Northern Territory. This species has recently been identified from the Northwest Highlands of Queensland, adjacent to the Northern Territory border (M.T.Mathieson, pers. comm.)

Conservation status: Restricted in distribution, but locally common in the upper Prince Regent River area, north to Mount Bomford and the King Edward River in Western Australia where it is not considered threatened. Conserved in the Prince Regent National Park and Mitchell River National Park. Listed as Data Deficient in the Northern Territory and Least Concern in Queensland.

Ecology: Grows in shallow sand or rich humus soils, often amongst *Triodia* tussocks on rough sandstone and sandstone pavements on plateaux. In the Kimberley, often growing with *Micraira brevis, M. dunlopii* and *M. lazaridis* and also associated with *Acacia richardsii*, *A. cyclocarpa*, *Borya subulata*, *Byblis filifolia, Calochilus barbarossa*, *C. kimberleyensis*, *Cymbopogon ambiguus*, *Cyperus pygmaeus*, *Dicliptera armata*, *Drosera cucullata*, *D. subtilis*, *Eriocaulon* sp., *Eucalyptus rupestris*, *Fimbristylis* sp., *Gompholobium subulatum*, *Gomphrena affinis*, *Grevillea wickhamii*, *Hibiscus leptocladus*, *Ipomoea eriocarpa*, *Lechenaultia* aff. *filiformis, Mitrasacme laricifolia*, *Murdannia graminea*, *Ricinocarpos rosmarinifolius*, *Rhynchospora* sp., *Stackhousia intermedia*, *Stylidium ceratophorum*, *S.* aff. *osculum*, *S. notabile*, *S.* aff. *quadrifurcatum*, *Thysanotus chinensis*, *Triodia* spp., *Trithuria lanterna*, *Typhonium* sp. Prince Regent River (R.L. Barrett & M.D. Barrett RLB 1716), *Utricularia chrysantha*, *U. magna* and *U. quinquedentata*.

Phenology: Flowers and fruits mainly December–February, but sometimes as late as early April under ideal conditions.

Affinities: Similar to *P. dockrillii* but differs by possession reflexed lateral sepals appressed to the ovary, erect not curved dorsal sepal, labellum insectiform with oblanceolate laminar broadly obtuse and beak-like at apex, central callus ridge beset with lateral accessory penicillate and spiky red calli; column slightly curved forward and lateral spreading, bluntly acute appendages. *Phoringopsis byrnesii* is also similar to but differs from *P. lavarackianum* by possession of glaucous leaf, and labellum callus much more densely covered with penicillate accessory calli.

Also similar to *Arthrochilus latipes*, differing in possession of 1 or 2 erect, elongate, lanceolate leaves, much longer than wide; resupinate flowers, smooth tepal bases; labellum hinge attached in centre of column foot, lacking a peltately attached supporting stalk and the strongly fungiform callus ornamented with long, thin penicillate glands (Jones *et al.* 2006; Jones 2021).

Notes: This species is unusual in its habitat preferences, growing amongst sandstone or on pavement margins dominated by *Triodia* spp.

Common names: Spinifex orchid, Sandstone truffle orchid.

Spiranthes Rich., *Orchid. Europ. Annot.* 20, 28, 36 (1817), *nom. cons. Lectotype*: *Spiranthes spiralis* (L.) Chevall., *typ. cons.*, designated by M.L.Greene, *Prop. Brit. Bot.* 100 (1929).

Orchiastrum Ség., *Pl. Veron.* 3: 252 (1754), *nom. rej. Type*: not designated.

Triorchis Millán, *Jac. Pet. Opera*: t. 68, f. 7 (1765), *nom. inval.*

Helictonia Ehrh., *Beitr. Naturk.* 4: 148 (1789), *nom. nud. Type*: *Ophrys spiralis* L.

Aristotelea Lour., *Fl. Cochinch.*: 522 (1790), *non* L'Heret (1784). *Type*: *Aristotelea spiralis* Lour. (*non Ophrys spiralis* L.).

Gyrostachis Pers., *Syn. Pl.* 2: 511 (1807), *nom. provis.*

Tussacia Raf. Sch. ex Desv., *Observ. Pl. Angers*: 91 (1818). *Type*: not designated.

Gyrostachys Pers. ex Dumort., *Fl. Belg.*: 134 (1827). *Type*: *G. spiralis* (L.) Pers. ex Blume, selected by Kuntze, *Rev. Gen. Pl.* 2: 663 (1891).

Monustes Raf., *Fl. Tellur.* 2: 87 (1837). *Type*: *Monustes australis* (R.Br.) Raf.

Triorchis Petiver ex Nieuwl., *Amer. Midl. Naturalist* 3: 122 (1913), *nom. superfl.*

Notes: Delimitation of species within *Spiranthes* has been difficult to achieve due to widespread distributions, local variation, high phenotypic plasticity (Pierce & Cribb 2002; Chen *et al.* 2009; Jones & Bates 2015; Pace & Cameron 2017; Tao *et al.* 2018; Pace *et al.* 2019) and hybridisation (Suetsugu *et al.* (2020). Some species complexes are now being resolved using molecular data (Dueck *et al.* 2014; Surveswaran *et al.* 2017, 2018; Frericks *et al.* 2018; Fan & Huang 2019; Pace *et al.* 2019). There has been particular confusion over the application of the name *Spiranthes sinensis* (Pers.) Ames, a matter hopefully now settled by Pace *et al.* (2019).

Spiranthes sinensis (Pers.) Ames, *Orchidaceae* 2: 53 (1908). *Neottia sinensis* Pers., *Syn. Pl.* 2(2): 511 (1807). *Aristotelea spiralis* Lour., *Fl. Cochinch.* (edn 1); 2: 522 (1790). *Epidendrum aristotelia* Raeusch., *Nom. Bot.* (edn. 3); 265 (1797), *nom. superfl. Ibidium spirale* (Lour.) Makino, *J. Jap. Bot.* 3(7): 37 (1926). *Spiranthes aristotelia* (Raeusch.) Merr., *Philippine J. Sci.* 15(3): 230 (1919). *Spiranthes indica* Lindl. ex Steud., *Nom. Bot.* (edn 2); 2: 625 (1841), *nom. inval. Spiranthes spiralis* (Lour.) Makino, *J. Jap. Bot.* 3(7): 25 (1926), *nom. illeg.* *Type*: China: Guangdong: 'Canton' [Guangzhou], *s.d.*, *Loureiro 522-1* (holo: P).

Neottia australis var. *chinensis* Ker Gawl., *Bot. Reg.* 7: pl. 602 (1821). *Type*: China: cultivated in England, Mr. Griffin's conservatory at Lambeth, *s.d.*, *collector unknown* (holo: Illustration: Bot. Reg. 7: pl. 602 (1821)).

Spiranthes pudica Lindl., *Collect. Bot.* t. 30 (1821). *Type*: China: Cultivated in England, July, *collector unknown* (holo: K).

Spiranthes neocaledonica Schltr., *Bot. Jahrb. Syst., Pflanzen. Pflanzengeog.* 39: 51 (1906). *Type*: New Caledonia: North Province: Ou-Hinna, Jan 1903, *R.Schlechter 15594* (holo: B†).

Spiranthes papuana Schltr. in F.W.L.Kraenzlin (ed.), *Repert. Spec. Nov. Regni Veg. Beih.* 1: 46–47 (1911). *Type*: Papua New Guinea: on flats near the Kenejia Base, *c.* 150 m, Oct. 1908, *R.Schlechter 18338* (holo: B†).

Illustration: N.Hallé, *Fl. Nouv. Caledonie* 8: 478, pl. 190 (1977); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 613 pl., fig. (2021), as *S. papuana*.

Terrestrial *herbs* with perennating rhizome, 10–40 cm tall. *Rhizome c.* 3 mm diam.; roots many, thickened and fleshy, 22-45 mm long, *c.* 2 mm diam., tubers absent. *Stem* erect, leaves clustered towards the base. *Leaves* 2–4 per plant, linear, 40–125 mm long, 5–7 mm wide, pale green, 1-veined, weakly canaliculate in section, apex broadly acute. *Inflorescence* up to 40 cm tall, terete, glabrous, with 2 or 3 sterile bracts sheathing the peduncle, 8–9 mm long, subulate and long-acute, green; flowers *c.* 33, spirally arranged, clustered towards the upper one-fourth of the peduncle with flowers opening from the base, many at anthesis simultaneously. *Flowers* curving forward from the ovary apex, widely open, *c.* 2.8 mm wide, *c.* 3.4 mm long, upper 3 tepals fused except for slight apical notches, and fused at base with lower 2 tepals, pink with a white labellum, glabrous. *Bracts* green, subequal to or slightly shorter than ovary, +/- narrowly cymbiform, 4–6 mm long, *c.* 2 mm wide, attenuate, thin-fleshy, glabrous, sheathing the base of flower, margin white. *Dorsal sepal* conjoined with 2 petals into a 3-toothed structure, pale at the base, grading to dark pink, glabrous, lanceolate, 1.5–1.7 mm long, *c.* 0.8 mm wide, obtuse. *Lateral sepals* fused at base to each other and to petals, pale at the base, grading dark pink, glabrous, lanceolate, 1.5–1.7 mm long, *c.* 0.7 mm wide, obtuse. *Petals* pale at the base, grading dark pink, glabrous, irregular in shape, 1.5–1.7 mm long, *c.* 0.7 mm wide, apex obtuse. *Labellum* white, exceeding tepals, concave, distinctly divided into hypochile and epichile with a constriction in the middle, glabrous on the outer surface, *c.* 3.5 mm long; hypochile dilated at the base, concave, ovate, *c.* 3.0 mm long, 2.0–2.8 mm wide, attached at the base of short foot below the column, with one semi-globular gland on each side, lobes suborbicular with entire margins, raised upwards till the constriction; epichile semi-tunicate, slightly flabellate, *c.* 1.3 mm long, *c.* 1.0 mm wide, margin undulate, slightly crenulate to denticulate or almost fimbriate with some papillose hairs on the front semi-tunicate part, apex abruptly broadly rounded. *Column* green-white, obconical, *c.* 1.5 mm long, 0.3 mm at the base, 0.5 mm wide towards the apex, base cordate, *c.* 0.5 mm long, glabrous, *c.* 1/3 the length of the labellum; stigma at the apex on the lower side, green in colour. *Rostellum* well developed. *Pollinarium* yellow, long clavate, with a deep cleft. *Ovary* +/- sessile, glabrous, green, short ellipsoid, slightly curved at apex 2.0–2.8 mm long, 1.2–1.6 mm wide. *Capsule* short-ellipsoid, 4.2–5(–6) mm long, 1.8–2.8(–3.3) mm wide, glabrous. (Figure 21)

Selected specimens examined: WESTERN AUSTRALIA: Mount Elizabeth Station [precise locality withheld], 15 June 2016, *M.D.Barrett & V.English MDB 5294* (PERTH). QUEENSLAND: near Blencoe Falls, 1979, *B.Gray 1311* (CNS).

Fig. 21. *Spiranthes sinensis*. A. Inflorescence. B, C. Close-up of inflorescence and flowers. Voucher: *M.D.Barrett & V.English MDB 5294* (PERTH). Photos by M.D. Barrett.

PAPUA NEW GUINEA: Kaindi, 2000 m, 12 May 1959, *L.J.Brass 29513* (CANB); Boridi, 4500 ft, 13 Sept. 1935, *C.E.Carr 10299* (BM, CANB); Finesterre Range, Tep Tep to Nokopo track, 27 Mar. 1990, *M.A. Clements 6302* (CBG); Oro Province, Nyola dry lake, Owen Stanley Ranges near Kokoda Trail, 2200 m, 22 Apr. 1990, *M.A.Clements 6948*, *P.Ziesing*, *D.Benzing* & *E.Dauncey* (CBG); Lake Kutaba, between Ridge Camp and Moro Camp, Iagifu Ridge, 29 June 2000, *M.A.Clements 10012* (CANB); Moro base camp grounds, 4 July 2000, *M.A.Clements 10252* (CANB); eastern side Lake Myola No. 1. Subdistrict. Kokoda District, 22 July 1974, *J.R.Croft et al. LAE 61950* (A, BRI, CANB, E, K, L, MU, NSW); Boana, Morobe District, 3000 ft, 6 Oct. 1959, *E.E.Henty N.G.F. 11572* (CANB, LAE); Mannasat, Cromwell Mountains, Huon Peninsula, Morobe District, 7500 ft, 21 July 1964, *R.D.Hoogland 9403* (CANB); Kindi, Wau, 2200 m, 14 May 1979, *A.Kaire 58* (A, BFC, CANB, K, L, LAE); Bonenau Village, Baniara subdistrict, Milne Bay District, 1000 m, 19 Aug. 1969, *R.Pullen 8089* (CANB, LAE); Keribiya-Tambil Road, Kaugel Valley, Hagen subdistrict, 7100 ft, 16 July 1957, *R.G.Robbins 450* (CANB); near Ebenda, Anga Valley, Southern Highlands District, 6600 ft, 16 July 1961, *R.Schodde 1464* (CANB).

Distribution: North Kimberley, Queensland, New Guinea, New Caledonia, China, Lao, Vietnam, Japan, Malaysia, Indonesia.

Conservation status: In Western Australia, known only from a single plant at one location on a pastoral station in the north-west Kimberley, in a swamp, potentially threatened by grazing pressures and/or water extraction. Only one collection is known from Queensland. Conservation Codes for Western Australian Flora: Priority 1. Further survey is required to determine whether the single plant seen was the result of adventitious dispersal, or is part of a persistent population.

Ecology: The single known specimen from Western Australia was growing in a permanently wet, perched mound spring, with Poaceae, Cyperaceae and *Utricularia* spp. Collections from New Guinea are mostly from peaty sedge swamps.

Phenology: Flowering in July in the Kimberley, May to August in New Guinea.

Affinities: Related to *S. australis*, which differs most obviously in the moderately to densely pubescent inflorescence rachis (Pace *et al*. 2019).

Notes: In a recently published paper, Frericks *et al.* (2018) highlighted the difficulties in determining the status and application of names in the *S. sinensis* complex. They revealed that significant molecular differentiation exist between plants collected and determined as this species from across the range from Nepal, China, Japan, Malaysia and Australia. The delimitation of *S. sinensis* has been highly problematic, but a combined morphological and molecular study has refined the concept of this species (Pace *et al*. 2019).

Common names: Chinese Spiranthes, Tiny spiral orchid.

Zeuxine Lindl., *Collect. Bot. App.* no. 18: 1 (1826) (as '*Zeuxina*'); *Orth. Scelet.*, 9 (1826) (as '*Zeuxina*'), *nom. cons.* *Lectotype*: *Z. strateumatica* (L.) Schltr., designated by P.J.Cribb, *Taxon* 48: 49 (1999).

Adenostylis Blume, *Bijdr. Fl. Ned. Ind.*: 414 (1825). *Type*: not designated.

Psychechilos Breda, *Gen. Sp. Orchid. Asclep.* 2: t. 9 (1829). *Type*: *P. gracilis* Breda.

Tripleura Lindl., *Edwards's Bot. Reg.* 19: t. 1618 (1833). *Type*: *T. pallida* Lindl.

Strateuma Raf., *Fl. Tellur.* 2: 89 (1837), *nom. illeg.* *Type*: *S. zeylanica* Raf., *nom. illeg.* (= *Orchis strateumatica* L.)

Monochilus Wall. ex Lindl., *Gen. Sp. Orchid. Pl.*: 486 (1840), *nom. illeg.* *non* F.E.L.Fischer & C.A.Meyer (1835); *Haplochilus* Endl., *Ench. Bot.*: 113 (1841). *Type*: not designated.

Heterozeuxine T.Hashim., *Ann. Tsukuba Bot. Gard.* 5: 21 (1986). *Type*: *H. odorata* (N.Fukuyama) T.Hashim.

Zeuxinella Aver., *Updated Checkl. Orchids Vietnam*: 96 (2003). *Type*: *Zeuxine vietnamica* Aver.

Notes: The circumscription of *Zeuxine* has been reduced to exclude *Rhomboda* Lindl. (Ormerod 1995), a position supported by Pridgeon *et al.* 2003).

Zeuxine oblonga R.S.Rogers & C.T.White, *Proc. Roy. Soc. Queensland* 32: 120, fig. 2 (1921). *Lectotype*: Queensland: Kamerunga (Barron R.), *E.Cowley s.n.* (lecto: AD!), designated by M.A.Clements, *Austr. Orchid Res.* 1: 147 (1989).

Residual syntypes: MacKay, *L.J. Nugent s.n.* (syn: AD 97720146A, *n.v.*); Daintree R., *G. Rosenstrom s.n.* (syn: AD 97720146B, *n.v.*).

Illustrations: Nicholls, *Orchids Austr.* 97, t. 53 (1969); D.L.Jones, *Native Orchids Austr.* 352, pl., fig. (1988); G.Wightman, *The Orchadian* 9(12): 281, f. 2 (1990); Dockr., *Austr. Indig. Orchids*. vol. 1; 46, fig. (1992); P.H.Weston in G.J.Harden, *Fl. New S. Wales* 4: 222, fig., pl. 15 (1993); T.Bishop, *Field guide orchids New S. Wales Vict.* 178, fig. 426 (1996); D.L.Jones, *Compl. Guide Austr. Orchids* 351, fig., pl. (2006); J.Woinarski *et al.*, *Lost from our landscape* 100, pl. (2007); A.P.Brown *et al.*, *Orchids West. Austr.*, pls p. 402, 405 (2008); K.Stephens & D.Sharp, *Fl. N. Stradbroke Isl.* 239, pl. (2009); Brown *et al.*, *Field Guide Orchids of Western Australia*, pls p. 475, 503 (2013); D.L.Jones, *Compl. Guide Austr. Orchids* (edn 3); 472 pl., fig. (2021).

Rhizomatous *herb*, 10–35 cm tall, deciduous, forming loose colonies, *Rhizome* prostrate, 2–4 mm thick, fleshy, with wiry roots. Leaf-bearing stems fleshy, 5–15 cm tall, bearing 3–7 scattered leaves with a terminal rosette above; cauline leaves drying first, generally all leaves dry at anthesis. *Leaves* sessile, sheathing at the base, lamina 30–80 mm long, 12–30 mm long, ovate to elliptical, often oblique, acute, thin textured, glabrous, margins often undulate, pale green. *Inflorescence* a terminal spike, 5–30 cm tall, the peduncle greatly exceeding the rachis, 1–2 mm diam, pinkish, subtended by 2 or 3 small sheathing bracts; peduncle, rachis, bracts, ovaries and sepals hirsute. *Ovaries* erect, elongate, asymmetric, 8–12 mm long, *c.* 1 mm diam.; floral bracts 4–12 mm long. *Flowers* 2–30, dense along spike, resupinate, 4–6 mm long; sepals dull green, hairy; petals white, labellum white; dorsal sepal hooded, 4–6 mm long, 1.5–2 mm wide, ovate; lateral sepals 3–4 mm long, 1–1.5 mm wide, narrow triangular or subovate, acute; petals 3.5–6 mm long, 1.5–2.5 mm wide, oblong; labellum 4–6 mm long, 3–4 mm wide, deeply saccate, with two rounded, linear or reniform calli *c.* 0.5 mm long; lower lip divided, lobes *c.* 2 mm long, 2 mm wide, oblong, margins often irregular; column *c.* 1 mm long, stout; stigmatic lobes ovoid, sacs containing a viscid substance; rostellum inclined forwards, *c.* 1.5 mm long, with two widely separated subtriangular lobes exceeding the rostrum apex; anther dorsal, 2-celled, *c.* 1 mm long. Pollinia 2, clavate, elongate, yellow. *Capsule* erect, hirsute, dehiscent; peduncle not elongated in fruit. (Figure 22).

Specimens examined: WESTERN AUSTRALIA: Point Spring, Ord River plains, 43 km ENE of Kununurra on Leguna access track, 26 Jul. 1996, *A.A.Mitchell 4031* (Broome Ag. Dept.; CANB); Point Springs, 43.34 km from Kununurra Post Office on a bearing of 21 degrees, 30 Aug. 2004, *A.A.Mitchell 7825* (CANB, PERTH); Point Spring, Ord River plains, 43 km ENE of Kununurra, 7 Sept. 2003, *G. & N. Sankowsky Sanko 2181* (PERTH).

Distribution: Endemic to Australia. Recorded near Kununurra in the North Kimberley, from the Keep River to the Adelaide River in the Northern Territory and scattered from Cape York Peninsula in north Queensland south to Coffs Harbour in New South Wales.

Conservation status: In Western Australia, known only from one location in a nature reserve in the north-east Kimberley which is potentially threatened by weeds, disturbance from cattle and pigs, and expansion of adjacent agriculture. Considered Vulnerable in the Northern Territory (Woinarski *et al.* 2007). Conservation Priority for Western Australia Flora: Priority 2 (Western Australian Herbarium 1998 onwards).

Fig. 22. *Zeuxine oblonga*. A. Habit. B. Leaf rosette. *c.* Base of stem and leaves. D. Inflorescence. E, F. Flowers. Vouchers: A: *A.A.Mitchell 4031* (Broome Ag. Dept.); B–F: *G. & N. Sankowsky Sanko 2181* (PERTH). Photos by R.L. Barrett (A); G. Sankowsky (B–F).

Ecology: Grows around springs in evergreen rainforest habitats, in deep leaf litter.

Phenology: Flowers July–September in the Kimberley.

Affinities: The only other species recorded for mainland Australia is *Z. polygonoides* (F.Muell.) P.J.Cribb which has since been transferred to the genus *Rhomboda* Lindl. *Zeuxine oblonga* is very similar to material collected from across the Pacific in Fiji and Samoa and where the earliest names appears to be *Z. samoensis* Schltr. (1906) which predates *Z. oblonga* by 14 years. However, it is premature to make any changes as all species are very close and it is essential that DNA be employed in delimiting species concepts.

Notes: Further investigation of species boundaries is required in the genus *Zeuxine*. It is possible that the material from Western Australia should be referred to the name *Z. gracilis* (Breda) Blume which was first described in 1829 from material collection in Java where is common and widespread, however Ormerod (2018) applies the name *Z. gracilis* to a different taxon than the one found in Australia. This species is also very similar as the recently re-discovered *Zeuxine exilis* Ridl., from Christmas Island (Du Puy *et al.* 1993).

A comparative molecular analysis is required to establish the true nature of the relationships between these species before undertaking any taxonomic changes.

Common name: Common jewel orchid.

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A classification for edible citrus: an update, with a note on *Murraya* (Rutaceae)

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Abstract

In the light of the continuing threat of huanglongbing, an update of the author's 1997 classification for edible citrus is presented and a new combination in *Murraya* J.Koenig is proposed.

Introduction

The continuing international disaster wrought by the bacterial disease huanglongbing (formerly known as citrus greening, the most severe form of which is associated with *Candidatus* 'Liberibacter asiaticus' (CLas, originally from South Asia; it is now widespread in Asia reaching New Guinea, the Americas and now Africa) in the citrus industries of much of the world has led to the need for a workable classification of the genus *Citrus* L. and its allies, notably *Murraya* J.Koenig, which genus is known to include species, notably *M. paniculata* (L.) Jack, the orange jasmine (Mabberley 2016), harbouring the bacterium (Beattie & Barkley 2009; Hall et al., 2013; Ajene et al. 2019, 2020). Some *Citrus* species, notably Australian ones, and hybrids have shown some resistance to the disease, though the evolutionary explanation for this is elusive (Folimonova et al. 2009, Ramadugu et al. 2016). Breeding programs inspired by this finding would inevitably have a long lead time in terms of introduction of resistant citrus to the trade and orchard.

Encouragingly, very recent research has focused on comparative expression analysis of small RNAs and messenger RNAs between HLB-sensitive cultivars and HLB-tolerant taxa, such that candidate natural defence genes potentially responsible for HLB tolerance have been identified (Huang et al., 2021). One of these candidate regulators from the Australian finger lime (*Citrus australasica* F.Muell.) is an antimicrobial peptide (AMP), named stable antimicrobial peptide (SAMP), which has been shown to kill *Liberibacter crescens* (Lcr), a Liberibacter strain in culture, and to prevent infections of *C*Las and 'solanacearum' strains in greenhouse trials. These peptides not only reduce disease symptoms but also induce immunity to fresh infections; these promising results need confirmation in field trials. Meanwhile it has also been mooted that CRISPR technology can also be brought to bear on the problem (Wheatley & Yang 2021).

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Citrus

Published some 25 years ago in this journal, the first of two precursors (Mabberley 1997, 1998) for the account of Rutaceae-Aurantioideae in *Flora of Australia* (Mabberley 2013), was an attempt to bring order to the chaotic nomenclature then obtaining within the literature on the commercially significant species of the genus *Citrus*, most taxa in the trade being hybrid, homoploid, apomictic (occasionally out-crossing) clones: previous systems had recognised 1–167 'good' species. Building on the pioneering chemotaxonomic work of the Polish-American botanist Rainer Scora (1928–2016), the 'basic' species (Scora 1975) then held to be the parents of commercially significant citrus were set out and their names typified; the cultivated hybrids formed between them were named and those names typified; for the first time the oranges, sweet and sour, with the grapefruit and their backcrosses were accommodated in cultivar groups within *Citrus* ×*aurantium* L. (*C. reticulata* Blanco × *C. maxima* (Burm.) Merr.), a single binomial, as mandated by the *International Code of Nomenclature for algae, fungi, and plants* (ICN; Turland et al. [eds] 2018) for all hybrids and backcrosses between two species. With continuously improving elucidation, updates, additions and refinements, reflecting such advances, have been published since (e.g. Mabberley 1998, 2002, 2004, 2013, 2017, 2018; Zhang & Mabberley 2008; Wearn & Mabberley 2016; Mabberley & Xu 2022), such that these contributions can be considered a series of evolving materials leading towards a projected monograph of the genus *Citrus*.

Other workers have published a draft genome, and pinned down the origin, of true wild mandarin, one of Scora's basic species (Wu et al. 2014, 2021; Wang et al. 2018; Mabberley & Xu 2022) and the draft genome of a sweet orange ('Valencia') has also been published (Xu et al. 2013). Over the last ten years, in particular, there has been a welcome series of publications of molecular work on *Citrus* systematics, effectively expanding on the 1997 framework (see especially the important synthesis of molecular work by Ollitrault et al. 2020 and commentary by Mabberley 2021, though there have been further developments since) through bringing clarity and solutions to long-standing questions. In the light of all this, it now seems appropriate, not only to provide an update of the 1997–2018 classifications published by the author, but also to take the opportunity to add further significant species and hybrids encountered in commerce, particularly in Australia. Not least, this account of the current state-of-play, effectively a 'skeletal' monograph of the genus *Citrus*, provides pointers to conservation imperatives in the truly autochthonous, non-apomictic taxa likely critical in plant-breeding for disease-resistance and other useful traits. Particularly concerning in this regard, though, is the fact that no unquestionably autochthonous populations of either citron (*C. medica* L.) or pomelo (*C. maxima*), two of the six 'basic' species of commercial citrus, have so far been definitively identified.

Conspectus

In the accounts of accepted species and hybrid names in the conspectus below only synonyms commonly encountered today are noted; others are covered in the publications cited above. Many of yet other published names of cultivated citrus have no type specimens and exiguous or scarcely diagnostic descriptions, making their identity dubious (see Tanaka 1930 for an earlier lament) and their continued use valueless (though some may in fact represent known hybrid combinations enumerated below - or yet others). Moreover, the literature is littered with conclusions based on misidentified taxa, besides names applied in ways completely at odds with their type specimens (where they exist), while even modern molecular work is sometimes unaccompanied by citation of herbarium vouchers, making identification of sampled taxa equivocal and thereby interpretation of consequent phylogenetic trees problematic.

Citrus L., *Sp. Pl.* 2: 782 (1753); Kubitzki, *Fam. Gen. Vasc. Pl.* 10: 349 (2011); Mabberley, *Fl. Australia* 26: 504 (2013).

Type: *Citrus medica* L.

Citreum Tournef. ex Mill., *Gard. Dict.*, abr. ed. 4: [338] (1754), nom. superfl. pro *Citrus* L.

Type: *Citrus medica* L.

Aurantium Tournef. ex Mill., *Gard. Dict.*, abr. ed. 4: [160] (1754); *Citrus* sect. *Aurantium* (Mill.) Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated, but all included taxa now referred to *Citrus* ×*aurantium* L.

Limon Tournef. ex Mill., *Gard. Dict.*, abr. ed. 4: [788] (1754).

Type: not indicated, but all included taxa now referred to *Citrus* ×*limon* (L.) Osbeck.

Sarcodactilis C.F.Gaertn., *Suppl. Carp.*: 39, t. 185 (1805).

Type: *S. helicteroides* C.F.Gaertn. = *Citrus medica* L. 'Fingered'.

Poncirus Raf., *Sylva Tellur.*: 143 (1838).

Type: *P. trifoliata* (L.) Raf. = *Citrus trifoliata* L.

Papeda Hassk., *Flora* 25, 2 Beibl. 1: 42 (1842); *Citrus* sect. *Papeda* (Hassk.) Miq., *Fl. Ned. Ind.* 1, 2: 529 (1859) & Tanaka, *Stud. Citrol.* 3: 169, 170 (1929) isonym; *Citrus* subg. *Papeda* (Hassk.) Burkill, *Gard. Bull. Straits Sett.* 5: 220 (1931).

Type: *P. rumphii* Hassk. = *C. hystrix* DC.

Oxanthera Montrouz., *Mém. Acad. Roy. Sci. Lyon, Sect. Sci.* ser. 2, 10: 186 (1860).

Type: *O. fragrans* Montrouz. = *Citrus oxanthera* Beauv.

Pseudaegle Miq., *Ann. Mus. Bot. Lugd.-Bat.* 2: 83 (1865), nom. superfl. pro *Poncirus* Raf.

Type: *P. sepiaria* (DC.) Miq., nom. illeg. = *Citrus trifoliata* L.

Eremocitrus Swingle, *J. Agric. Res.* 2: 86 (1914); *Citrus* subg. *Eremocitrus* (Swingle) Burkill, *Gard. Bull. Straits Sett.* 5: 218 (1931).

Type: *E. glauca* (Lindl.) Swingle = *C. glauca* (Lindl.) Burkill.

Fortunella Swingle, *J. Washington Acad. Sci.* 5: 167 (1915); *Citrus* subg. *Fortunella* (Swingle) Burkill, *Gard. Bull. Straits Sett.* 5: 218 (1931).

Type: *F. margarita* (Lour.) Swingle = *C. japonica* Thunb.

Microcitrus Swingle, *J. Washington Acad. Sci.* 5: 570 (1915); *Citrus* subg. *Microcitrus* (Swingle) Burkill, *Gard. Bull. Straits Sett.* 5: 219 (1931).

Type: *M. australasica* (F.Muell.) Swingle = *C. australasica* F. Muell.

Pleurocitrus Tanaka, *Stud. Citrol.* 3: 169, 181 (1929).

Type: *P. inodora* (F.M.Bailey) Tanaka = *Citrus inodora* F.M.Bailey

Citrus subg. *Archicitrus* Tanaka, *Stud. Citrol.* 3: 169, 170 (1929).

Type: not indicated.

Citrus sect. *Limonellus* Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated.

Citrus sect. *Citrophorum* Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated.

Citrus subg. *Metacitrus* Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated.

Citrus sect. *Osmocitrus* Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated.

Citrus subg. *Acrumen* Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated.

Citrus sect. *Microacumen* Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated.

Citrus sect. *Pseudofortunella* Tanaka, *Stud. Citrol.* 3: 170, 171 (1929).

Type: not indicated.

Clymenia Swingle, *J. Arnold Arbor.* 20: 251 (1939).

Type: *C. polyandra* (Tanaka) Swingle = *Citrus polyandra* Tanaka.

×*Citroncirus* J.W.Ingram & H.E.Moore, *Baileya* 19: 171 (1975).

Type: ×*C. webberi* J.W.Ingram & H.E.Moore (non *Citrus* ×*webberi* Wester [1915] =?) = *Citrus* ×*insitorum* Mabb.

×*Citrofortunella* J.W.Ingram & H.E.Moore, *Baileya* 19: 169 (1975).

Type: not indicated.

+*Citroponcirus* H.Wu et al., *J. Trop. Subtrop. Bot.* 12: 179 (2004).

Type: +*C.* 'Hormish' (*C. trifoliata* L. + *C.* ×*aurantium* 'Ponkan').

Description: see Kubitzki (2011), Mabberley (2013).

Notes: Recent molecular evidence counters some earlier molecular findings (see Appelhans et al. 2021 for discussion), so *Feroniella* Swingle is here removed from earlier synonymies. With hybridisation right across *Citrus*, the maintenance of infrageneric taxa in such a relatively small genus is rather pointless (Mabberley 2002, 2021).

Australia has six native species (besides the three listed below, there are *Citrus garrawayi* F.M.Bailey, *C. gracilis* Mabb. and *C. inodora* F.M.Bailey, which shows some resistance to huanglongbing (Folimonova et al. 2009, Ramadugu et al. 2016); see Mabberley 1998, 2013), China five (besides the four listed below, there is *C. mangshanensis* S.W.He & G.F.Liu from southern China; see Wu et al. 2014, Gmitter et al. 2020, Ollitrault et al. 2020). Other apparently truly autochthonous species not listed below are: *C. halimii* B.C.Stone (West Malesia, allied to *C. japonica* Thunb.; Mabberley & Kiew 2005, Luro et al. 2022); *C. indica* Tanaka (NE India, a close ally of *C. medica*) and *C. latipes* (Swingle) Tanaka (NE India, very similar to *C. cavaleriei* H.Lév. ex Cavalerie and included in it by Luro et al. 2002; it shows some resistance to CLas; Folimonova et al. 2009, Ramadugu et al. 2016)); the rest (in need of modern revision) being from the south-west Pacific islands: *C. neocaledonica* Guillaumin, *C. oxanthera* Beauvis. and *C. undulata* Guillaumin (besides *Oxanthera brevipes* B.C.Stone) from New Caledonia; *C. polyandra* Tanaka (*Clymenia polyandra* (Tanaka) Swingle), with round pulp-vesicles as in *C. australasica* (and *C. mangshanensis*), *C. wakonai* P.I.Forst. & M.W.Sm., *C. warburgiana* F.M.Bailey and *C. wintersii* Mabb. (Mabberley 1998, 2013) all from Papua New Guinea, making a grand total of about 25 species, at most, for the whole genus.

Autochthonous, outcrossing species in commerce or parental species of commercially significant hybrids

Rather than give 'varietal' names to sets of cultivars using the *International Code of Nomenclature for Algae, Fungi and Plants* (Turland et al. 2018, it seems more appropriate to follow customary practice with cultivated plants and use cultivar groups according to the *International Code of Nomenclature for Cultivated Plants* (Brickell et al. 2016), as in Mabberley 1997, 2021; Zhang & Mabberley 2008; cf. Webber 1943, e.g. *Citrus japonica* (Oval Kumquat Group) 'Nagami'. Names are presented below in alphabetical order.

1. ***Citrus australasica*** F.Muell., *Fragm.* 1: 26 (1858).

Type: Australia, Queensland, Moreton Bay, *W. Hill s.n.* (**MEL** (MEL 1059262) holo).

Common name: finger lime.

Description: Mabberley (2013: 507).

Distribution: Australia (south-east Queensland and north-east New South Wales).

Notes: Mueller (1858) also cited "Mueller" under specimens seen, but no such material is to be found at MEL. Formerly used synonym: *Microcitrus australasica* (F.Muell.) Swingle (see Mabberley 1998, 2013). Shows some resistance to huanglongbing (Folimonova et al. 2009, Ramadugu et al. 2016). Commonly seen cultivars in Australia (where very many more have been raised): 'Alstonville', 'Blunobia Pink Crystal', 'Durham's Emerald', 'Judy's Everbearing', 'Pink Ice', 'Rainforest Pearl'. A parent of *C.* ×*oliveri* Mabb. and *C.* ×*virgata* Mabb.; crossed with *C.* ×*otaitensis* (Risso & Poit.) Risso to give 'blood lime' (Mabberley 2004).

2. ***Citrus australis*** (Mudie) Planchon, *Hort. Donat.*: 18 (1858).

Basionym: *Limonia ? australis* A.Cunn. ex Mudie, *Pict. Australia*: 151 (1829).

Type: Australia, Queensland, Moreton Bay, 1829, *A. Cunningham* '26' (**BM** (BM013719093) lectotype designated by D.J. Mabberley, *Telopea* 7: 339. 1998); **G** (G00096611), **K** isolecto).

Common names: dooja, (Australian) round lime.

Description: Mabberley (2013: 509).

Distribution: Australia, south-east Queensland.

Notes: Formerly used synonym: *Microcitrus australis* (Mudie) Swingle (see Mabberley 1992, 1998, 2013). Shows some resistance to huanglongbing (Folimonova et al. 2009, Ramadugu et al. 2016). A parent of *C.* ×*virgata*.

3. ***Citrus cavaleriei*** H.Lév. ex Cavalerie, *Bull. Géogr. Bot*. 21: 211 (1911).

Type: "J'ai trouvé dans les bois, loin de toute habitation, dans les environs de Ma-Jo et de Kai-Tchéou [K'ai Chow], vers 1700 metres d'altitude". China: K'ai Chow 60 km NNE of Kweiyang (P5240963), *P.J. Cavalerie s.n.* (**P** [**NSW** photo] lectotype designated by D.J. Mabberley & P.G. Kodela, *Telopea* 18: 116 [2015]).

Common name: Ichang papeda.

Description: Zhang & Mabberley (2008: 91).

Distribution: south-west and south-central China.

Notes: Formerly used synonym: *C. ichangensis* Swingle (see Zhang & Mabberley 2008; Mabberley & Kodela 2015); *C. latipes* has also been referred here as *C. ichangensis* subsp. *latipes* Swingle. A parent of *C.* ×*junos*.

4. ***Citrus glauca*** (Lindl.) Burkill, *Gard. Bull. Straits Sett.* 5, Index: 3 (1932).

Basionym: *Triphasia glauca* Lindl. in Mitchell, *J. Exped. Trop. Austral.*: 353 (1848).

Type: Australia [Queensland, Dublin County, near junction of Maranoa & Merivale rivers], 17 Oct 1846, 'Tastes like Rue', *T.L. Mitchell 398* (**CGE** holo [transparency seen]; ? **BM** (BM013719095), **GH** (GH002451400), **K, L** (L0017830, 'subtropical New Holland 1846'), **NSW** (NSW 421084) iso).

Common names: limebush, wild lime, desert lime.

Description: Mabberley (2013: 509).

Distribution: eastern Australia.

Notes: Formerly used synonym: *Eremocitrus glauca* (Lindl.) Swingle (see Mabberley 1998, 2013). Of all *Citrus* species and hybrids so far examined (Folimonova et al. 2009, Ramadugu et al. 2016), *C. glauca* shows most resistance to huanglongbing. Successfully crossed in cultivation with *C. japonica*, *C. medica*, *C.* ×*limon* - to give 'eremolemons', with *C.* ×*aurantium* Sweet Orange Group - to give 'eremoranges', with *C.* ×*insitorum* - to give 'citrangeremos' and with *C. wintersii* (Swingle 1943: 365–366; Mabberley 1998, 2013).

5. ***Citrus hystrix*** DC., *Cat. Pl. Horti Monsp.*: 19, 97 (1813 '*histrix*') & *Prodr*. 1: 539 (1824 '*hystrix*').

Type: France [cult.], "Frutex spectabilis olim ex insula Mauritiana [Mauritius] (ubi forsan cultus) merit. Mercatori Nemauensi Roland a navarcha quodam allatus, et anno 1808 a D°. Roland horto Monspeliensi humanissime missus", Hérault, Montpellier, Jardin des plantes (G00209703), *Anon. s.n.* (**G-DC** holo?, fide D.J. Mabberley, *Gard. Bull. Singapore* 54: 187 [2002]).

Common names: makrut, Thai lime, leech-lime (N.B. the regrettably all-too-frequently used name 'kaffir lime' is to be strongly discouraged, as such a name is offensive to many people).

Description: Zhang & Mabberley (2008: 92).

Distribution: Myanmar and Thailand to Sumatra, east to New Guinea, though natural distribution probably obscured by cultivation, its having been carried far into the Pacific (A.C. Smith, *Fl. Vitiensis Nova* 3: 186, 1985), for example.

Notes: Formerly used synonyms: *C. combara* Raf., *C. macroptera* Montr.; commonly used synonym: *C. micrantha* Wester (see Mabberley 1998, 2022). A parent of *C.* ×*amblycarpa* and *C.*×*aurantiifolia* (see Ollitrault et al. [2020]; as accurately concluded by Bonavia [1886, 1888]); see also *C.* ×*latifolia*. N.B. Candolle later amended his '*histrix*' to '*hystrix*' and, according to Vincent Demoulin (pers. comm. 17 April 2022), this is indeed a correctible orthographic error in any case.

6. ***Citrus japonica*** Thunb., *Nova Acta Regiae Soc. Sci. Upsal*. 3: 199 (1780).

Type: Japan [cult.], *C.P. Thunberg s.n.* in Herb. Thunb. 17862 (**UPS-THUNB** holo; **S** S-G-1442 iso).

Description: Zhang & Mabberley (2008: 92).

Distribution: southern China.

Common name: kumquat (cumquat in Australia).

Notes: Formerly used synonyms: *C. margarita* Lour., *Fortunella japonica* (Thunb.) Swingle, *F. margarita* (Lour.) Swingle. Cultivar group status is appropriate to accommodate the cultivars with different fruit-shapes (see Zhang & Mabberley 2008): Round Kumquat Group e.g. 'Marumi' and Oval Kumquat Group e.g. 'Nagami'. A parent of: *C.* ×*floridana*, *C.* ×*georgiana*, *C.* ×*microcarpa*, *C.* ×*oliveri*; other crosses, e.g. with *C.* ×*junos* (q.v.), not in commercial cultivation in Australia.

7. ***Citrus maxima*** (Burm.) Merr., *Interpr. Herb. Amboin*. 46: 296 (1917).

Basionym: *Aurantium maximum* Burm., *Herb. Amboin. Auctuar*. 6–7: Index [16] (1755).

Type [icon]: 'Limo decumanus' Rumpf, *Herbarium Amboin*. 2: t. 24 f. 2 & B. 1741; fide A.C. Smith, *Fl. Vitiensis Nova* 3: 522 (1985).

Common name: pomelo (pummelo)

Description: Zhang & Mabberley (2008: 93).

Distribution: ?SE Asia (Thailand posited by Scora & Nicolson [1986]), but no unequivocally 'wild' populations have been identified, though some specimens from northern Thailand and southern Lao could perhaps be autochthonous.

Notes: Formerly used synonyms: *C. decumana* L., *C. grandis* (L.) Osbeck (see Mabberley 1997). Cultivar group status is appropriate for the cultivars with different fruit-shapes.

Commonly seen cultivar in Australia: 'Chandler'. A parent of *C.* ×*aurantium*; see also *C.* ×*insitorum*, *C.* ×*latifolia*, *C.* ×*limon*.

8. ***Citrus medica*** L., *Sp. Pl.* 2: 782 (1753).

Type: "Habitat in Asia, Media, Assyria, Persia"; [icon] 'Citreum' in Tournefort, *Inst. Rei Herb*. 620. t. 396, 1700, lectotype designated by D.M. Porter in C.E. Jarvis et al. (ed.), *Regnum Veg*. 127: 34. 1993 (see Mabberley 1997, 2018, 2022).

Common names: citron, etrog.

Description: Zhang & Mabberley (2008: 93)

Distribution: ?NE India, but no unequivocally 'wild' populations have been identified.

Notes: Cultivar group status is appropriate to accommodate the cultivars with different fruit-shapes and flavours. 'Etrog' is one of the citrons used in the Feast of the Tabernacles. Commonly seen cultivars: 'Corsican', 'Fingered' (Buddha's hand; 佛手 fo shou). The male parent of *C.* ×*limon,* and *C.* ×*otaitensis*. Florentine citrons (*C. medica* var. *florentina* Risso) are backcrosses with lemons, so referable to *C.* ×*limon* (q.v.).

9. ***Citrus reticulata*** Blanco, *Fl. Filip*.: 610 (1837), nom. cons. prop.

Type: China [cultivated], Hubei Province, Wuhan, Huazhong Agricultural University (material grown from seed from Hunan Province, Mangshan region [24° 98' N, 112° 88' E]), 25 July 2022, *Q. Xu s.n.* (KUN 1543827) KUN, typ. cons. prop. ; HIB, PE.

Common name: wild mandarin; it is perhaps the same as *C. reticulata* var. *austera* Swingle, *J. Wash. Acad. Sci.* 32: 25 (1942). "Mandarins" in international commerce are referable to a cultivar group of *C.* ×*aurantium* – see Mabberley (1997), Curk et al. (2015), Ollitrault et al. (2020), Mabberley & Xu (2022), while *C. mangshanensis* is now excluded, as confirmed to be a distinct species – see above.

Description: [var. *austera*] Swingle (1943: 415).

Distribution: southern China.

Notes: The name, like *C. nobilis* Lour. before it, was applied to pure mandarin, though the types of both are in fact *C.* ×*aurantium* cultivars. Mabberley & Xu (2022) have proposed a solution to stabilise the nomenclature through typification based on pure wild mandarin. Apparently in cultivation only as a rootstock (Swingle 1943: 415; Ollitrault et al. 2020); possibly conspecific with *C. daoxianensis* S.W.He & G.F.Liu (Curk et al. 2015; Ollitrault et. al. 2020). A parent of *C.* ×*amblycarpa, C.* ×*aurantium*, *C.* ×*junos*, *C.* ×*otaitensis, C.* ×*tachibana*; see also *C.* ×*georgiana*, *C.* ×*insitorum*, *C.* ×*latifolia, C.* ×*limon*, *C.* ×*oliveri*.

10. '***Citrus ryukyuensis***'; G.Wu et al., *Nature Comm*. 12: 4377 (2021) [nom. inval.].

Distribution: Japan (Ryukyu Islands).

Notes: Shortly to be formally named and described (G. Wu in litt. 12 April 2022), though it is possibly the same as *C. nobilis* var. *spontanea* T.Itô, *J. Coll. Sci., Tokyo Imp. Univ*. 12: 361 (1900). https://www.biodiversitylibrary.org/item/31156#page/461/mode/1up

Apparently not in cultivation. A parent of *C.* ×*tachibana* (Wu et al. 2021).

11. ***Citrus trifoliata*** L., *Sp. Pl*., ed. 2, 1: 1101 (1763).

Type: "Habitat in Japonia"; [icon] 'Karatats banna' Kaempfer, *Amoen. Exot*. Fasc. 801, 802 (1712), lectotype designated by W.T. Swingle in Webber & Batchelor, *Citrus Industry* 1: 368 (1943).

Common name: trifoliate orange.

Description: Zhang & Mabberley (2008: 91).

Distribution: Central & north China.

Notes: Commonly used synonym: *Poncirus trifoliata* (L.) Raf. (see Mabberley 2002).

Shows some resistance to huanglongbing (Folimonova et al. 2009, Ramadugu et al. 2016). A parent of *C.* ×*insitorum*. Commonly seen cultivars in Australia are largely rootstocks but 'Monstrosa' ('Flying Dragon') is also grown as an ornamental.

Hybrid taxa

In the literature, many of the following apomictic, (usually) homoploid, hybrid taxa found naturalised in tropical Asia have been mistaken for autochthonous sexual species.

Growers need names for the principal hybrid groups in cultivation, even though many of those groups have complex parentage, so making 'hybrid formulae' unwieldy. Moreover, rather than give 'varietal' names to sets of cultivars using the *International Code of Nomenclature for Algae, Fungi and Plants* (Turland et al. 2018), it seems more appropriate to follow customary practice with cultivated plants and use cultivar groups according to the *International Code of Nomenclature for Cultivated Plants* (Brickell et al. 2016), as in Mabberley 1997, 2021; Zhang & Mabberley 2008, e.g. *Citrus* ×*aurantium* L. (Sweet Orange Group) 'Valencia'.

Those citrus crops cultivated in Australia are listed below. Other names recognised by Ollitrault et al. (2020) for hybrid taxa, perhaps not grown in Australia, are: *Citrus* ×*lumia* Risso (*C. medica* × *C. maxima*), though this name has apparently not been properly typified, and some "lumias" seem to be pure *C. medica* with others perhaps involving *C.* ×*limon* (cf. '*C.* ×*pseudolumia*' an invalidly published name [Ollitrault et al. 2020; but for which combination there may be published names already – see above] for *C. hystrix* × *C. maxima* × *C. medica*, the Borneo or baboon lemon), while yet another "lumia", the Pomme d'Adam, is now referred to *C.* ×*aurantiifolia* (Curk et al. 2016).

1. ***Citrus*** ×***amblycarpa*** (Hassk.) Ochse, *Ind. Vruchten*: 217 + t. 104 (1927), pro sp.

Basionym: *C.* ×*limonellus* Hassk. var. *amblycarpa* Hassk., *Flora* 25, Beibl. 2: 43 (1842).

Type: Indonesia [cult.], Java, Bogor (not preserved – see Tanaka [1930: 233]).

Common name: jeruk limo (or limau), nasnaran mandarin.

Description: Backer & Bakhuizen van den Brink (1965: 109).

Parentage: (male) *C. hystrix* × (female) *C. reticulata* (Curk et al. 2015; Ollitrault et al. 2020).

Notes: A common market fruit (for sambal) in Java, its leaves besides fruits (jeruk) sold for use in fish dishes in Sarawak (Peter Boyce & Sin Yen Wong pers. comm. 21 April 2022), but also grown, particularly by Indonesian people, in Australia.

2. ***Citrus*** ×***aurantiifolia*** (Christm.) Swingle, *J. Wash. Acad. Sci*. 3: 465 (1913), pro sp.

Basionym: *Limonia* ×*aurantiifolia* Christm., *Vollst. Pflanzensyst*. 1: 618 (1777), pro sp.

Type [icon]: 'Limonellus sive Limon Nipis' Rumpf, *Herb. Amboin*. 2: t. 29 (1741) lecto designated by B.C. Stone in M.D. Dassanayake & F.R. Fosberg, *Revis. Handb. Fl. Ceylon* 5: 424 (1985).

Common names: (Key or Mexican) lime, alemow.

Description: Zhang & Mabberley (2008: 94)

Parentage: (male) *C. medica* × (female) *C. hystrix* (Bonavia [1886, 1888: 82] was the first to realise *C. hystrix* was in the parentage; Curk et al. 2016, Ollitrault et al. 2020; Mabberley 2022).

Notes: Commonly used synonym: *C.* ×*macrophylla* Wester. A parent of *C.* ×*floridana* and *C.* ×*latifolia*.

3. ***Citrus*** ×***aurantium*** L., *Sp. Pl.* 2: 782. 1753, pro sp.

Type: "Habitat in India." Probably cultivated in Europe, Herb. Linn. No. 937.2, upper row of leaves (**LINN** lecto designated by D.J. Mabberley, *Telopea* 7: 170, 1997).

Common names: orange, grapefruit, chinotto, clementine, ortanique, satsuma, tangelo, tangerine, tangor (and the 'mandarins' in modern commerce).

Description: Zhang & Mabberley (2008: 95).

Parentage: (male) *C. reticulata* × (female) *C. maxima* including many back-crosses (Scora 1975; Mabberley 1997, 2004; Ollitrault et al. 2020).

Notes: Commonly used synonyms: '*C.* ×*clementina*' auctt., *C.* ×*deliciosa* Ten., *C.* ×*nobilis* Lour., *C.* ×*paradisi* Macfad., *C* ×*poonensis* Tanaka, *C.* ×*sinensis* (L.) Osbeck, *C.* ×*tangelo* J.W.Ingram & H.E.Moore, *C.* ×*tangerina* Yu. Tanaka, *C.* ×*unshiu* (Swingle) Marcow. (see Mabberley 1997; Zhang & Mabberley 2008; Wu et al. 2014). Commonly seen cultivars in Australia: 'Barnfield', 'Delta Seedless', 'Hamlin', 'Lane Late', 'Leng', 'Ruby', 'Tarocco Ippolito', 'Valencia', 'Washington Navel' ('Baia', an older name; see also 'Bahia Navel' being grown in what is now the Royal Botanic Garden, Sydney in 1828 – Bowman [1955]), 'Winter Sunrise' - all Sweet Orange Group; 'Duncan', 'Flame', 'Marsh', 'Ray Ruby', 'Rio Red', 'Star Ruby', 'Texas Pink', 'Thompson', 'Wheeny' - all Grapefruit Group; 'Minneola', 'Seminole' - Tangelo Group; 'Wilking' - ('Tangor Group'), 'Clementine', 'Dancy', 'Ellendale', 'Honey Murcott', 'Murcott', 'Ortanique', 'Temple', 'Wilking' - Tangerine or Tangor Group; 'Afourer', 'Cleopatra', 'Emperor', 'Imperial', 'Miho Wase', 'Owari', 'Ponkan' - Satsuma or Mandarin Group, 'mandarins'; Seville oranges (Sour Orange Group; see Saunt 2000: 140), e.g. 'Bouquet', are used for marmalade, while 'Myrtifolia' (*C.* ×*myrtifolia* Reider), chinotto is apparently a bud mutation of a sour orange (Swingle 1943: 489–490). A parent of *C.* ×*floridana*, *C.* ×*insitorum*, *C.* ×*limon*.

4. ***Citrus*** ×***floridana*** (J.W.Ingram & H.E.Moore) Mabb., *Telopea* 7: 337 (1998).

Basionym: ×*Citrofortunella floridana* J.W.Ingram & H.E.Moore, *Baileya* 19: 170 (1975).

Type [icon]: "Evstis [sic = 'Eustis'] limequat (No 48798), grown in the greenhouse at Washington, D.C.", *J. Agric. Res*. 23: [237] t. 4 (1923).

Common name: limequat.

Description: Swingle & Robinson (1923).

Parentage: (male) *C. japonica* × (female) *C.* ×*aurantiifolia* (Swingle & Robinson 1923; Mabberley 1998).

Note: Formerly used synonym: ×*Citrofortunella floridana* (see Mabberley 1998). Cultivars include 'Eustis' and 'Lakeland' (Saunt 2000: 137).

5. ***Citrus*** ×***georgiana*** Mabb., *Blumea* 49: 490 (2004).

Type: Germany [cult. from material received from Citrus Arboretum, Winterhaven, Florida, 1996; see http://members.aol.com/agrumivoss/thomasv.jpg], Lower Saxony, Stade, Jork, Moorende 149, Voss's Töpferei und Citruspflanzen-Spezialgärtnerei, Sept. 2004 (L4151394), *B. Voss 2* (**L** holo; **NSW** iso).

Common name: citrangequat.

Description: Swingle & Robinson (1923).

Parentage: (male) *C.* ×*insitorum* × (female) *C. japonica* (Swingle & Robinson 1923; Mabberley 2004).

Note: Cultivar in commerce: 'Thomasville'.

6. ***Citrus* ×*insitorum*** Mabb., *Gard. Bull. Sing.* 54: 193 (2002).

Basionym: ×*Citroncirus webberi*, J.W.Ingram & H.E.Moore, *Baileya* 19: 171 (1975), non *Citrus* ×*webberi* Wester (= ?).

Type [icon]: USDA Yearbook 1904: 228 tt. XI n. 716, XII f. 1–3 ('Rusk').

Common name: citrange, citrumelo.

Description: Webber (1943: 654).

Parentage: (male) *C.* ×*aurantium* × (female) *Citrus trifoliata* (Webber 1943: 656; Mabberley 2002).

Notes: Formerly used synonyms: ×*Citroncirus webberi* (see Mabberley 2002). Besides conferring tristeza-resistance, it shows some resistance to huanglongbing (Albrecht & Bowman 2011). Commonly seen cultivars in Australia (largely as rootstocks): 'Carrizo', 'Rusk', 'Troyer' (which is the parent, with *C.* ×*otaitensis*, of another synthesized rootstock), 'Willits'.

7. ***Citrus* ×*junos*** (Makino) Tanaka, *Sieb. Sens. Tor. Hyakun. Kin. Ronbunshu*: 65 (1924), pro sp.

Basionym: *C.* ×*aurantium* subsp. *junos* Makino, *Bot. Mag. (Tokyo)* 15: 165 (1901).

Type: Japan [cult.], "Prov. Musashi: Tokyo, Bot. Gard. Koishikawa (Herb.! Sc. Coll. Imp. Univ. Tokyo, May 31, 1881)" (**TI** lectotype designated by S. Akiyama et al., *J. Jap. Bot.* 90: 261, 2015).

Common name: yuzu.

Description: Zhang & Mabberley (2008: 95).

Parentage: *C. cavaleriei* × *C. reticulata* (Swingle 1943: 427, though also including some contributions from *C. japonica* and *C. maxima*, according to García-Lor et al. 2015).

Notes: Several other Japanese citrus cultivars analysed by Shimizu et al. (2016) are also Ichang papeda/mandarin crosses (ichandarins), some with contributions from other taxa: such include *Citrus* ×*tamurana* Tanaka ex Takahashi (hyuganatsu, konatsu) and *C.* ×*sudachi* Shirai (sudachi), amongst the whole array of hybrid "mandarins" selected and highly favoured in Japan.

8. ***Citrus* ×*latifolia*** (Yu.Tanaka) Tanaka, *Syst. Pomol.*: 140 (1951), pro sp.

Basionym: *Citrus* ×*aurantiifolia* var. *latifolia* Yu.Tanaka, *Agr. & Hort.* 9: 2346 (1934).

Type: Not preserved?

Common names: Persian lime, Tahiti[an] lime.

Description: Webber (1943: 624 as 'Tahiti Group')

Parentage: (male) *C.* ×*aurantiifolia* × (female) *C.* ×*limon* (Mabberley 2004; Zhang & Mabberley 2008; Curk et al. 2016, Olitrault et al. 2020).

Notes: A sterile triploid, it is one of the most commonly grown of all limes and is the lime least susceptible to huanglongbing (Folimonova et al. 2009). Cultivars grown in Australia: 'Bearss' (very similar to the original 'Tahiti'), 'Idemor'. It is rather surprising that there is not an older Latin name for this ubiquitous hybrid which is said to have reached Australia by 1824 and, in 1828, was being grown as 'Persian' in what is now the Royal Botanic Garden, Sydney (Bowman 1955); it reached California from Tahiti (presumably hence the common name, readily confusable with *C. otaitensis* 'Otaheite' – see below) in the mid-1800s.

9. ***Citrus* ×*limon*** (L.) Osbeck, *Reise Ostindien*: 250 (1765 as '*limonia*'), pro sp.

Basionym: *Citrus medica* var. *limon* L., *Sp. Pl.* 2: 782 (1753).

Type [icon]: 'Limon vulgaris' in Ferrari, *Hesperides* 191, 193, 1646 lectotype designated by D.J. Mabberley, *Telopea* 7: 169 (1997, q.v. for discussion of Osbeck's publication).

Common names: lemon, bergamot, limetta, sweet lemon, Florentine citron.

Description: Mabberley (2013: 505).

Parentage: (male) *C. medica* × (female) *C.* ×*aurantium* (Scora 1975, Mabberley 1997, Curk et al. 2016, Ollitrault et al. 2020).

Notes: Formerly used synonyms: *C.* ×*aurantium* subsp. *bergamia* (Risso) Engl., *C.* ×*bergamia* (Risso) Risso & Poit., *C.* ×*limetta* Risso (see Mabberley 1997, 2022). Parent of *C.* ×*latifolia*. Cultivar group status is appropriate to accommodate cultivars with different fruit-shapes and flavours e.g. Sweet Lemon Group, Bergamot Group. Commonly seen cultivars in Australia: 'Eureka', 'Fino' ('Primofiori'), 'Lisbon', 'Meyer', 'Verna', 'Villafranca', 'Yen Ben'. Florentine citrons (formerly *C. medica* var. *florentina* Risso), are backcrosses (formerly *C.* ×*limonimedica* Lush.) with citron. The Florentine citron is one of the components (the other being a sour orange) of a celebrated graft-chimaera, the bizzaria, (*Citrus* 'Bizzaria') which arose in Firenze, Italy, in the seventeenth century (Ragionieri 1927).

10. ***Citrus*** ×***microcarpa*** Bunge, *Enum. Pl. Chin. Bor.*: 10 (1833), pro sp.

Type: China [cult.], "Chine boreal" (P02441071), *Anon.* in Herb. Bunge *s.n.* (**P** ?holo, fide D.J. Mabberley, *Telopea* 7: 337, 1998).

Common names: calamondin, calamansi.

Description: Swingle (1943: 357).

Parentage: *C. reticulata* × *C. japonica* (Swingle 1943: 415; Mabberley 1998; Curk et al. 2016).

Notes: Formerly used synonyms: ×*Citrofortunella microcarpa* (Bunge) Wijnands, ×*C. mitis* (Blanco) J.W.Ingram & H.E.Moore, *Citrus* ×*mitis* Blanco (see Mabberley 1998, 2002). A parent of *C.* ×*oliveri*. Calamansi is important in the soft drink industry, especially in the Philippines.

11. ***Citrus*** ×***oliveri*** Mabb., *Blumea* 49: 490 (2004).

Type: Germany [cult. from material received in 1996 from Citrus Arboretum, Winterhaven, Florida, USA; see http://members.aol.com/agrumivoss/faust.jpg), Lower Saxony, Stade, Jork, Moorende 149, Voss's Töpferei und Citruspflanzen-Spezialgärtnerei (L4196570), *B. Voss 3* (**L** holo).

Common names: faustrimedrin, sunrise lime.

Description: Swingle (1943: 360)

Parentage: *C. australasica* × *C.* ×*microcarpa* (Mabberley 2004).

Note: Shows some resistance to huanglongbing (Folimonova et al. 2009, Ramadugu et al. 2016).

12. ***Citrus*** ×***otaitensis*** (Risso & Poit.) Risso, *Fl. Nice*: 86 + t. [7] (1844 '*taitensis*'), pro sp.

Basionym: *C.* ×*aurantium* var. *otaitensis* Risso & Poit., *Hist. Nat. Orang.*: 66 + t. 27 (1819).

Type [icon]: Risso & Poit., *Hist. Nat. Orang.*: t. 27 [1819] lectotype designated by Mabberley (2022, accepted).

Common names: rough (or bush - Australia) lemon, Rangpur lime, Canton lemon, Volkamer lemon.

Description: Webber (1943: 626, as Rangpur).

Parentage: *C. medica* × *C. reticulata* (Curk et al. 2016).

Notes: See Mabberley (2022 in press) for discussion of this name, which has to be corrected from 'taitensis'. Commonly used synonyms: '*C.* ×*limonia*' auctt., non *C.* ×*limon* (L.) Osbeck ('*limonia*'; see Mabberley 1997), *C.* ×*jambhiri* Lush., *C.* ×*volcameriana* (Risso & Poit.) V.Ten. & Pasq. Used as a rootstock tolerant of tristeza (Saunt 2000: 149); a fashionable flavouring ingredient in gin. Crossed with *C. australasica* to give 'blood lime', while one rootstock in cultivation is a synthesized hybrid with *C.* ×*insitorum* 'Troyer'. According to Saunt (2000: 151) 'Otaheite' (Tahitian orange) is a sweet (as opposed to sour) cultivar, apparently the original dwarf introduction to Europe (the type); it is often seen in USA as a pot-plant, when only 30 cm tall producing fruits in winter (Webber 1943: 630).

13. ***Citrus*** ×***tachibana*** (Makino) Tanaka, *Bult. Sci. Fak. Terk. Kjusu Imp. Univ*. 1: 31 (1924), pro sp.

Basionym: *C.* ×*aurantium* var. *tachibana* Makino, *J. Soc. Hort. Jap*. 75: 2 [+ t., n.v.] (1896).

Type: Lost, cf. Swingle (1943: 421), or not preserved.

Common name: Tachibana (Japan)

Description: Swingle (1943: 421); Ohwi (1984: 585).

Parentage: *C. reticulata* × '*C. ryukyuensis*' (Wu et al. 2021).

Note: Tachibana is of great cultural significance to Japanese people, figuring in early poetry besides on modern coinage and the medal of the Order of Cultural Merit.

14. ***Citrus* ×*virgata*** Mabb., *Telopea* 7: 339 (1998).

Type: USA [cult.], Washington DC, USDA greenhouses, 'C.P. & B. no. 7775-E', 23 Oct. 1939, *W.T. Swingle s.n.* (NSW 418672) (**NSW** holo).

Description: Swingle (1943: 382).

Parentage: *C. australasica* × *C. australis* (Swingle 1943: 382; Mabberley 1998, 2013).

Notes: Cultivar commercial in Australia: 'Sydney Hybrid'. It shows some resistance to huanglongbing (Folimonova et al. 2009, Ramadugu et al. 2016) and has been successfully crossed with *C.* ×*aurantium* 'Clementine' (Mabberley 1998).

Murraya

It has been recognised that *Murraya paniculata* (L.) Jack s.s. is favoured by the psyllid vector of CLas (and is a transient host of the bacterium), whilst other currently recognised species formerly included within *M. paniculata* s.l., have not been recorded as such (George Beattie pers. comm., 12 April 2022). These include the Australian *M. lucida* (G.Forst.) Mabb., but also a mainland Asian taxon (Om 2017), for which the name *M. elongata* A.DC. ex Hook.f. has very recently been revived (see Nguyen et al. 2019, Mou et al. 2021). However, in their monographic treatment, Mou et al. (2021), unfortunately did not consider the first available name, *Chalcas intermedia* M.Roem.: the correct binomial in *Murraya*, when *M. paniculata* is used in the narrow sense, is therefore:

Murraya intermedia (M.Roem.) Mabb., **comb. nov.**

Basionym: *Chalcas intermedia* M.Roem., *Syn. Monogr.* 1: 48 (1846).

Type: India, Assam, Goalpara ('Gualpara'), 19 Aug. 1803 (E00940361), *F. Buchanan-Hamilton 1054* (**E** lectotype designated here).

Note: Max Roemer, copying material from Wight & Walker-Arnott (1834: 94), has a somewhat ambiguous description (in a key), but cites only one specimen, here chosen as lectotype. His confused description perhaps comes from consideration of a cited Roxburgh drawing now at **K** and probably referable to *M. paniculata s.s.*, orange jasmine.

[*Chalcas paniculata sensu* Lour., *Fl. Cochinch.*: 270 (1790), non L.]

Note: There is Loureiro material (BM000832568) at **BM**.

[*M. paniculata* sensu mult. auctt., p.p., non Jack (1820 quoad basionym)]

M. elongata A.DC. ex Hook.f., *Fl. Brit. India* 1: 503 (1875), **syn. nov**.; *Camunium elongatum* (Hook.f.) Kuntze, *Rev. Gen.* 1: 99 (1891).

Type: Myanmar, Kayin, "817 Taong-dang [i.e. Thandaung] Village near the houses 26 Novbr [1826]" (K001132323), *N. Wallich s.n.* [found after n. *6369* in *Herb. EIC*] (**K** holo).

Description: Mou et al. (2021: 392), as *M. elongata*.

Distribution: Mainland Asia (India to peninsular Malaysia). It is the geographical vicariant of *Murraya sumatrana* Roxb. (Sumatra and eastwards in Malesia) and the closely related *M. lucida* (east Malesia and western Pacific south to Australia); see Nguyen et al. (2019).

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Two new species of *Genoplesium* R.Br. *sensu lato* (Orchidaceae: Prasophyllinae) from the Central Coast of New South Wales

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Abstract

We describe two new species of Prasophyllinae from New South Wales, in the genus *Genoplesium* R.Br. following the generic classification currently in use at the National Herbarium of New South Wales. One of these new species, *Genoplesium branwhiteorum* M.A.M.Renner & P.H.Weston, which we name for the Branwhite family, has been known for nearly a decade under the informal name *Corunastylis* sp. Charmhaven (NSW896673). The other new species, *G. geminatum* M.A.M.Renner & Towle has been confused with both *G. rufum* (R.Br.) D.L.Jones & M.A.Clem. and *G. trifidum* (Rupp) M.A.M.Renner, although it is more similar to *G. mucronatum* (Rupp) M.A.M.Renner and *G. tasmanicum* D.L.Jones, and possesses a combination of features of consistent expression supporting its recognition as a new species. Three new combinations are made. *Genoplesium cuspidatum* (D.L.Jones & L.M.Copel.) M.A.M.Renner, comb. nov. is based on *Corunastylis cuspidata* D.L.Jones & L.M.Copel., *Genoplesium laminatum* (Fitzg.) M.A.M.Renner, is based on *Prasophyllum laminatum* Fitzg. and *Genoplesium mucronatum* (Rupp) M.A.M.Renner is based on *Prasophyllum mucronatum* Rupp. [listed as a synonym of *G. rufum* in PlantNet].

Introduction

Australian orchid taxonomy presents an unusual, but perhaps not unique, situation wherein multiple competing classifications, at both species level and above, are applied simultaneously within a single country and even within single states and territories. This situation is the result of a very human tension between an enthusiasm for the rapid adoption of new insights into diversity and relationships borne of novel morphological and molecular data on the one hand; and a reluctance to make changes in the absence of complete knowledge on the other. To be fair, the extremes of both perspectives are equally unworkable. We may be misled by, or misinterpret, empirical data and so adopt new classifications that do not reflect real world diversity or history. But refusing to acknowledge novel data results in the same outcome, which is to persist with classifications that do not reflect real world diversity. The scientific method provisions us with inferential tools that allow us to further our knowledge of the world, through an observational approach to testing our understanding.

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Taxonomy falls within the purview of scientific inference because the names we use, at both species level and above, are formal placeholders for hypotheses of relationship, though the relationships among individuals and among species are of a different kind. These hypotheses, and by proxy their associated names, can be tested against agreed criteria associated with how well they reflect reality. The replication and scrutiny of those tests are integral to the scientific endeavour.

One of the lineages in which a consensus within Australia regarding generic circumscription has not yet been reached is the orchid tribe Prasophyllinae, comprising the named genera *Prasophyllum* R.Br., *Genoplesium* R.Br., *Paraprasophyllum* M.A.Clem. & D.L.Jones, *Mecopodum* D.L.Jones, *Cheiroteris* D.L.Jones, and *Corunastylis* Fitzg. At least four of these genera are widely used by orchid enthusiasts in New South Wales and across Australia (e.g. Jones 2021; Copeland & Backhouse 2022). However, only two genera, *Prasophyllum* and *Genoplesium*, are currently accepted by the National Herbarium of New South Wales, for reasons outlined below.

The first study suggesting that revision to the circumscription of *Genoplesium* was required was Clements e*t al.* (2002) who resolved *Prasophyllum australe* R.Br. as nested among three species of *Genoplesium*, *G. baueri* R.Br., *G. apostasioides* (Fitzg.) D.L.Jones & M.A.Clem., and *G. rufum* (R.Br.) D.L.Jones & M.A.Clem., but this relationship was unsupported. In this analysis the terminal branch leading to *G. baueri* was associated with the highest number of substitutions (116) of any in the tree. This may have been associated with alignment of the two spacer regions within the ribosomal RNA cistron (comprising partial sequences of 18S and 26S and full sequence of 5.8S, separated by internally transcribed spacers, ITS 1 and 2), for which satisfactory alignment across the Prasophyllinae is difficult to achieve (M.A.M. Renner *pers. obs.*). Inspection of an algorithmically aligned and manually edited matrix based on the sequences analysed by Clements *et al.* (2002) reveals, within the coding regions of the rRNA cistron, six unambiguous sites grouping *G. apostasioides* and *G. rufum;* two sites that unambiguously group *G. baueri* and *P. australe;* and four that group *G. baueri* with the other two *Genoplesium* (*Corunastylis*) species, suggesting that the majority of signal for the sister relationship between *G. baueri* and *P. australe* may reside in the equivocally aligned spacer regions.

The most recent changes to generic circumscription within the Prasophyllinae (Clements and Jones 2019) were based on a sample of 54 species representing all 6 recognised genera, from which nrITS sequence data were again obtained. This sampling is comprehensive, and some unexpected relationships were detected, including the nesting of *Mecopodum striatum* (R.Br.) D.L.Jones & M.A.Clem. among *Corunastylis* species, and the resolution of two lineages of *Prasophyllum sens. strict.*, for one of which the new genus *Paraprasophyllum* was proposed. It is not known what effect the alignment of these regions has on resolution of relationships among species within the Prasophyllinae as a whole, because the data underpinning the analyses presented by Clements and Jones (2019), and supporting the recognition of *Paraprasophyllum* among other insights, has not been published, contrary to standard practice. The widely acknowledged issues associated with equating nrITS gene trees and species trees were reviewed by Alvarez and Wendel (2003) and include, paralogy, reticulation, and incomplete lineage sorting, in addition to the standard challenges of homologising sites within indel-rich regions, which make this marker generally unsuitable for the inference of phylogenetic relationships when used alone. Assessing the quality of relationships inferred from the nrITS cistron is complicated by the absence of published data supporting published inferences, which is a decoupling of interpretation from evidence uncharacteristic of most biological sciences. The reasons why the National Herbarium of New South Wales has not adopted the revised generic circumscriptions proposed for the Prasophyllinae include the acknowledged issues associated with inferring species trees from the nrITS cistron alone and the non-trivial challenges associated with aligning nrITS1 and nrITS2 spacer regions across Diuridae, and even within the Prasophyllinae, associated with the risk that suboptimal alignment generates misleading phylogenetic signal. The National Herbarium of New South Wales continues to apply the generic concepts of Clements and Jones (1989) until the relationships of *Genoplesium baueri* have been fully resolved, and independently verified, with independent verification ideally coming from multiple low-copy nuclear loci.

It is encouraging that contemporary research into Australian orchid diversity is coupled with next generation sequencing technologies and sophisticated analyses of molecular and morphological variation (e.g. Nargar *et al.* 2018), which therefore presents an empirically rich platform for hypothesis-driven advances to our understanding of diversity within this family.

This paper is about the proposal of two new species of orchid from New South Wales, rather than generic circumscription. One of these new species has been known for nearly a decade under the informal name *Genoplesium* sp. Charmhaven (NSW896673) (also known as *Corunastylis* sp. Charmhaven). *Genoplesium* sp. Charmhaven (NSW896673) was first discovered in 2012 in the Central Coast region, and was immediately recognised as distinct. The other has either been recognised as a member of the *Genoplesium rufum* complex,

or confused with *G. trifidum*, but has not been formally or informally described. We describe both new species in the genus *Genoplesium* following the National Herbarium of New South Wales' position on generic circumscription within the Prasophyllinae, articulated in part above, while we await published evidence mandating the adoption of an alternative generic classification.

Taxonomic treatment

Genoplesium branwhiteorum M.A.M.Renner & P.H.Weston, sp. nov.

Type: Australia, New South Wales, Central Coast, Charmhaven, precise locality withheld, 18 February 2012, *R.J. Payne s.n.* (holo: NSW896673).

Corunastylis sp. Charmhaven (NSW896673), NSW Herbarium, PlantNet [https://plantnet.rbgsyd.nsw.gov.au/, accessed 3 Aug. 2022].

Genoplesium sp. Charmhaven (NSW896673), Herbarium, PlantNet [https://plantnet.rbgsyd.nsw.gov.au/, accessed 3 Aug. 2022].

Diagnosis: *Genoplesium branwhiteorum* is similar to *G. archeri* (Hook.f.) D.L.Jones & M.A.Clem., *G. sagittiferum* (Rupp) D.L.Jones & M.A.Clem. and *G. stephensonii* (D.L.Jones) J.M.H.Shaw in its green and cream flowers with prominent purple markings; the labellum with ciliate margins but the other tepal margins entire or nearly so, but is distinct in the sparse short cilia on the petal margins, the flowers around 6 mm wide with a column 2.2–3.3 mm tall with a fairly conspicuous column foot 0.5 mm long, and the broad triangular lower column wing lobe.

Etymology: Named after the Branwhite family, whose members have contributed to the understanding of many orchid species across New South Wales and, in particular, within the Central Coast region.

Terrestrial tuberous herb. Leaf to 19.5 cm long, 1.8 mm wide, slender, terete, mid green; free lamina c. 16 mm long (measured from base of terete part; 25 mm from tip to base of slit), 1.4 mm wide, linear-lanceolate, sheathing the scape, ending c. 8 mm above base of the first flower. Inflorescence length exposed outside of leaf to 40 mm long, bearing 3–15 closely spaced flowers on a peduncle 6–12 mm long above the leaf; flowers opening in sequence from the base; flowers sessile. Ovary ellipsoidal, curved, 2.5–3.8 mm long, nearly straight on abaxial margin, and curved on the adaxial margin, lengthening with age, slightly longer at maturity. Flowers porrect, c. 8.5 mm long between tip of dorsal sepal and tips of lateral sepals, 6 mm wide between tips of lateral petals; green and cream with deep maroon markings. Dorsal sepal 4.0–4.5 mm long by 2.0–2.1 mm wide, ovate, cucullate, glabrous, greenish cream, with 3 maroon veins and maroon margins. Lateral sepals 5.0–5.5 mm long, 1.3–1.4 mm wide, narrow-ovate, bent abaxially c. 1 mm above base through 45–100°, erect to ascending, slightly to prominently divergent, distally involute, thick-textured, pale at base, then maroon and maroon with green in outer 1/2–2/3, glabrous, apex obtuse, without a gland. Lateral petals 3.2–3.7 mm long, 1.0–1.2 mm wide, narrow-ovate, acute or shortly acuminate, apex without a gland, divergent, cream with 3 maroon veins and maroon margins, with entire or with very sparsely ciliate margins, with as few as 1 or 2 cilia on the margin; cilia mostly less than 0.1 mm long. Labellum 3.0–3.5 mm long, 1.5 mm wide, broadly oblong-ovate to slightly obovate, rounded distally, with recurved, mucronate apex, maroon, in upper two thirds, pale in the basal third, but with maroon marginal and medial markings, narrowed in proximal 2/3, thick and fleshy, the margins densely ciliate, cilia varying in length from < 0.1 mm long to 1.0 mm long, flexuous and often entangled; callus defined by its intense maroon pigmentation in the outer half, slightly elevated profile above the surrounding lamina, and the smaller projecting cells on its surface, extending almost to labellum apex, ligulate from a broad base which encompasses nearly the whole labellum width, channelled for basal 2/3 of its length, thickest in the basal half. Column 2.2–3.3 mm long, erect, with two prominent basal callosities; column foot present c. 0.5 mm long, projected forwards, curved upwards. Column wings shallowly divided to 1/5–1/6 the wing length by a narrow sinus with acute vertex into two lobes, upper triangular to triangular oblong, lower narrow triangular, each with an acute apex; the lower lobe finely papillate on its surface and margin papillae longer toward the apex of the lobe, and there mixed with cilia; upper lobe pale, lower lobe maroon. Anther 1.0 mm long, truncate. Stigma broad-elliptical, 0.8 mm long, 0.7 mm wide, tapering to a free, forward projecting truncate protrusion beneath the anther, surface uneven but not papillate. Pollinarium 1.0 mm long; pollinia 0.45 mm long, yellow, granular; hamulus 0.45 mm long; viscidium 0.3 mm wide. (Figures 1–4)

Fig. 1. *Genoplesium branwhiteorum* inflorescence from a plant at Lake Macquarie, not vouchered, photo by Brian Towle.

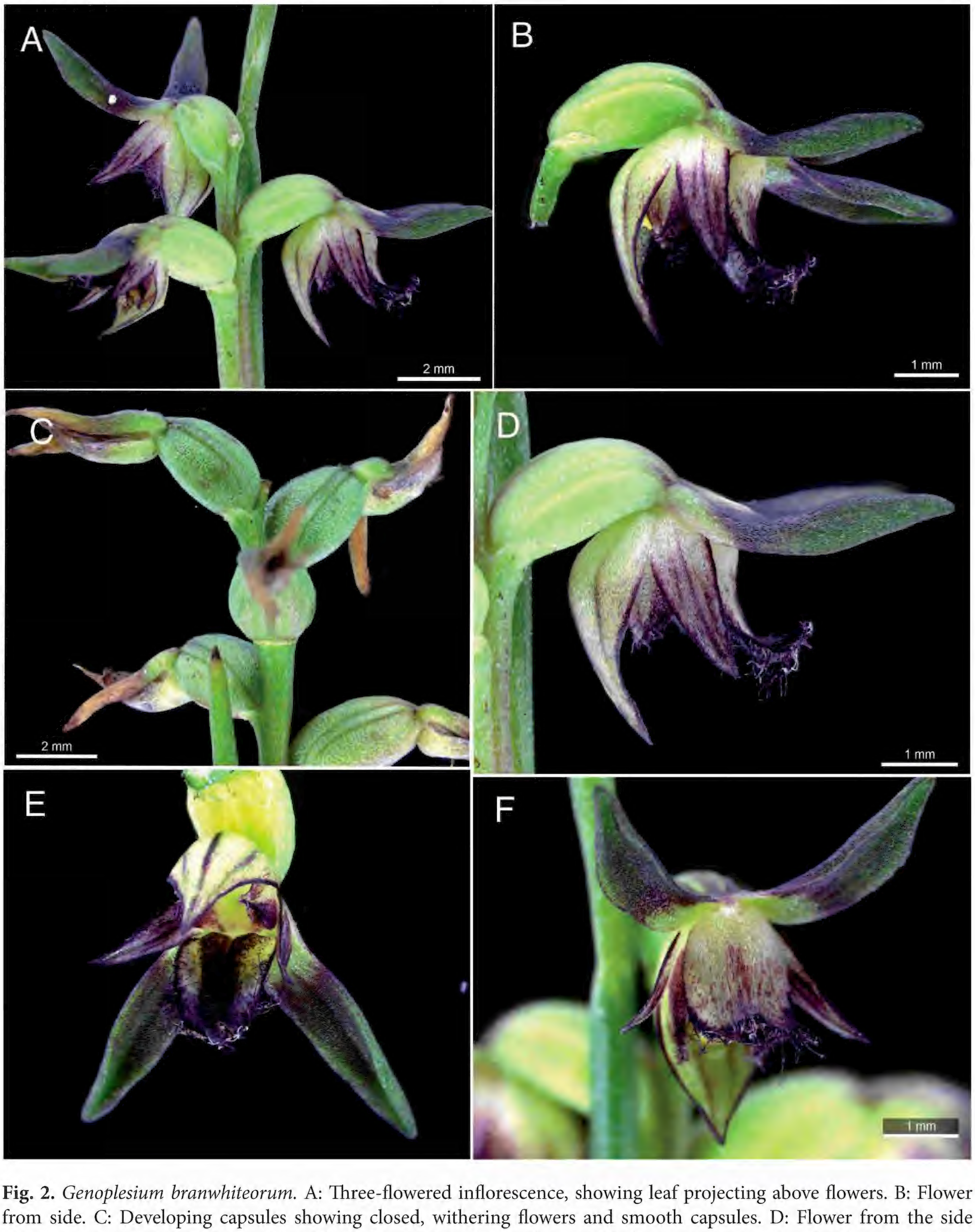

Fig. 2. *Genoplesium branwhiteorum.* A: Three-flowered inflorescence, showing leaf projecting above flowers. B: Flower from side. C: Developing capsules showing closed, withering flowers and smooth capsules. D: Flower from the side showing arrangement of sepals and petals. E: Flower from below showing labellum marginal cilia and pale regions either side of the dark pigmented callus, also the coriaceous inrolled lateral sepal apex. F: Flower in frontal view showing the labellum margin and ventral surface. All from NSW1114958.

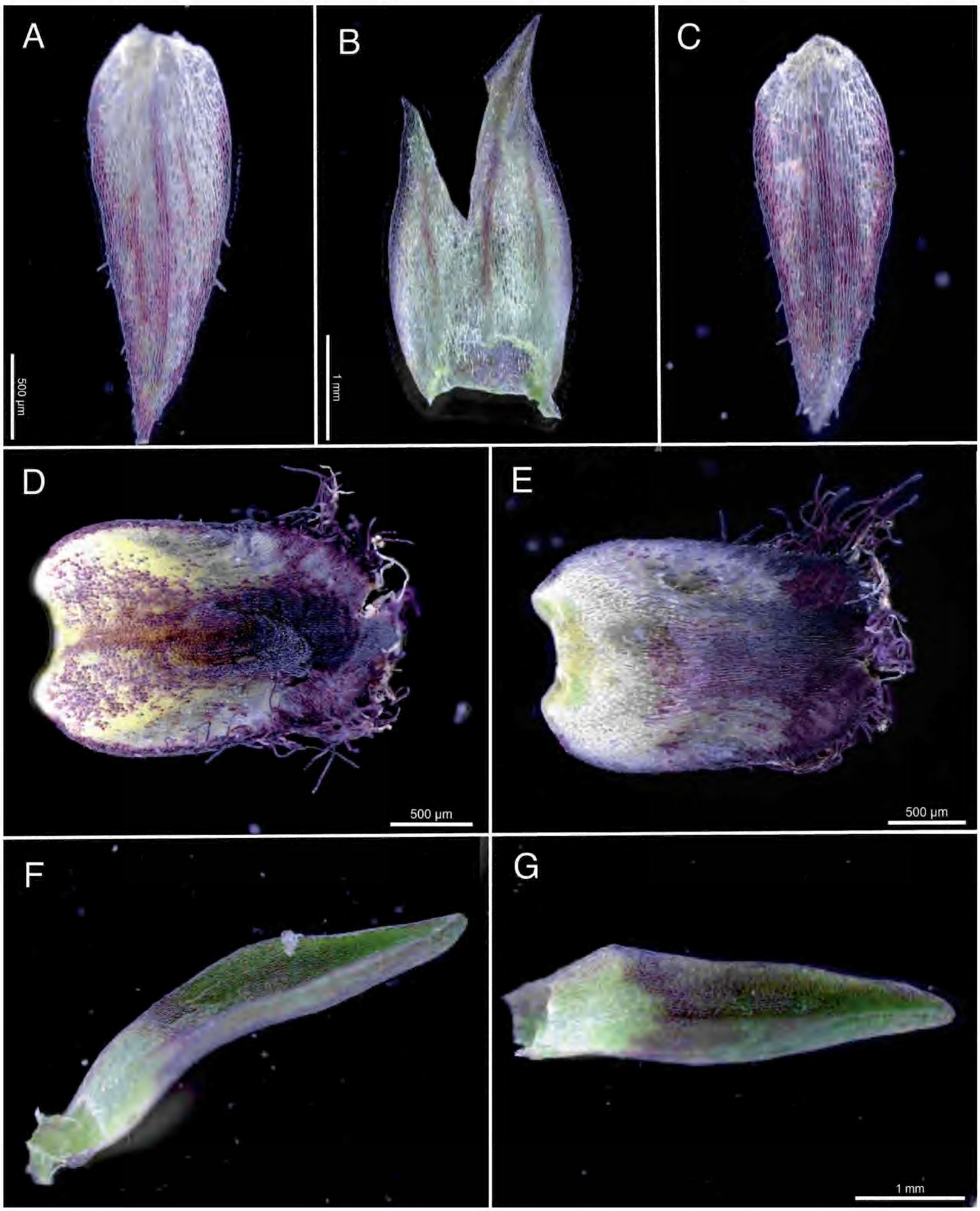

Fig. 3. *Genoplesium branwhiteorum.* A, C: Petal showing marginal and medial stripe and short sparse cilia on the petal margins. B: Dorsal sepal showing margins and medial stripes and acute apex. D: Labellum in dorsal view, showing marginal cilia, callus and pigmentation. E: Labellum in ventral view showing base and insertion and dense marginal cilia on outer margins. F, G: Lateral sepals showing pigmentation and texture. All from NSW1114958.

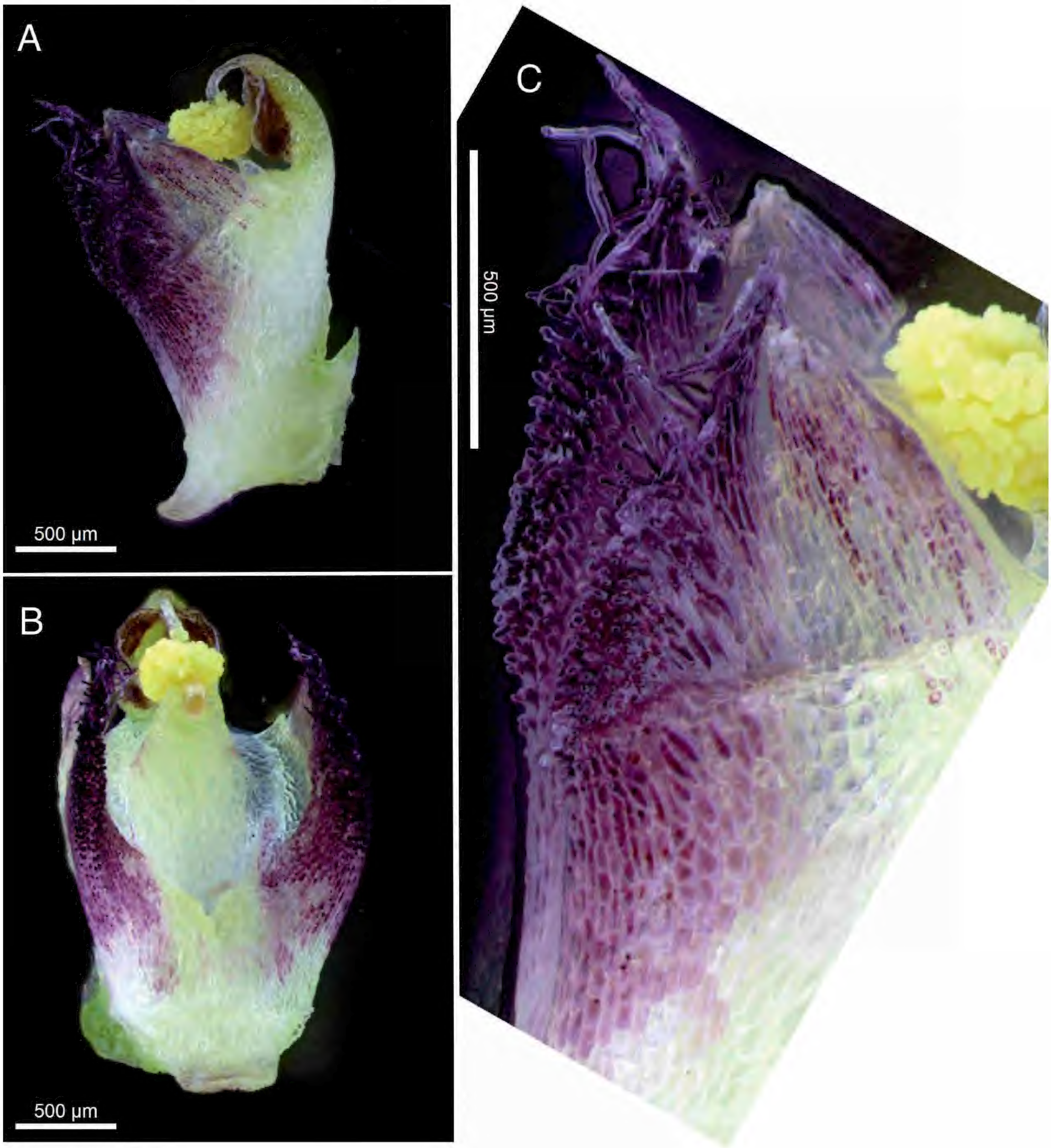

Fig. 4. *Genoplesium branwhiteorum.* A. Column in lateral view showing column wings, anther, pollen mass, and column foot, note pigmentation of the column wings. B. Column in frontal view showing the anther, pollen mass with stipe and viscidium resting over the apical projection of the stigma, the stigma and a basal recess at the fusion between the two column wings, note the long cilia on the lower column wing lobe apex, which grade into tall papilla below. C. Detail of the column wings. All from NSW1114958.

Distribution and ecology: Currently known from the Central Coast and Lake Macquarie Local Government Areas of NSW, where *G. branwhiteorum* has been recorded from the area bound by the localities of Morisset, Chain Valley Bay, Charmhaven and Bushells Ridge. We estimate the extent of occurrence (EOO) of *G. branwhiteorum* based upon all documented records of the species, to be 76.2 km^2 and its area of occupancy (AOO) to be 40 km^2. *Genoplesium branwhiteorum* has been observed growing in dry sclerophyll forests, heathlands and forested wetlands where it commonly occurs amongst a dense understorey of grasses and sedges. Dominant species include *Allocasuarina littoralis*, *Leptospermum juniperinum*, *Melaleuca nodosa*, *Callistemon linearis* and *Schoenus brevifolius*. The pollination biology of this species is unknown, however the near perfect rate of capsule development, in the absence of herbivory, suggests that it is at least facultatively autogamous. *Genoplesium branwhiteorum* is listed as critically endangered under both the NSW *Biodiversity Conservation Act 2016*, and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* as *Corunastylis/Genoplesium* sp. Charmhaven (NSW896673).

Recognition: *Genoplesium branwhiteorum* is similar to *Genoplesium archeri*, but differs from *G. archeri* in having fewer, larger flowers (3–15 flowers, 6 mm across, versus 10–20 flowers, 4.5–5 mm across in *G. archeri*), borne on a shorter inflorescence (1.4 cm long versus 2–3.5 cm long in *G. archeri*).

Genoplesium branwhiteorum is similar to *G. sagittiferum*, but can be distinguished by the sparse, short cilia present on the petal margins, a feature shared with *G. stephensonii*, but absent in *G. sagittiferum*.

Genoplesium branwhiteorum is also similar to *G. stephensonii*, but *G. stephensonii* has a shorter column c. 1.8–2.0 mm tall, and c. 0.7 mm wide at the base in lateral view; the column foot is curved upward, and is fairly narrow, only 0.25 mm wide at its apex; the lower margin and lower lobe of the column wing bearing long cilia, the apex of the lower wing lobe may also be long attenuate. In contrast, the column of *G. branwhiteorum* is taller, up to 3.3 mm tall, and wider at the base, where c. 1.1 mm wide in lateral view; the column foot is an obtuse protrusion from the base of the column and is 0.75 mm wide at its apex; the lower margin and lower lobe of the column wing bear short cilia or tall papillae, not long cilia, and the apex is acuminate but never attenuate.

Genoplesium branwhiteorum could be confused with ***Genoplesium cuspidatum*** (D.L.Jones & L.M.Copel.) M.A.M.Renner, comb. nov. (basionym: *Corunastylis cuspidata* D.L.Jones & L.M.Copel., *Australian Orchid Review* 82(6): 54 (2017)), but lacks the distinctive cuspidate sepal apices which characterise that species.

Genoplesium branwhiteorum is broadly sympatric with *G. insigne* D.L.Jones, and although the field aspects of *G. branwhiteorum* and *G. insigne* are very different, without colouration and on microscopic examination the two are rather similar in floral structure, except perhaps that *G. insigne* has rather more coriaceous column wings and entirely lacks cilia or any form of projection on the petal margins.

Notes: *Genoplesium branwhiteorum* is thought to hybridise with *G. insigne* to produce plants that bear a striking resemblance to *G. plumosum,* though one of us (MR) thinks these putative hybrids are actually *G. plumosum*. Further work on the breeding system and population genetics of *G. branwhiteorum* and other *Genoplesium* in the Warnervale area and surrounds is required to establish whether *G. branwhiteorum* does indeed hybridise with other species, and whether or not hybridisation presents any potential threats to the long-term genetic integrity of the known populations of this highly localised species.

Additional specimen examined: NEW SOUTH WALES: Central Coast, Lake Macquarie State Conservation Area, precise locality withheld, 19 March 2021, *M.A.M. Renner 9493* (NSW1114958).

Genoplesium geminatum M.A.M.Renner & Towle, sp. nov.

Type: Australia, New South Wales, Lake Macquarie, precise locality withheld, 10 February 2021, *M.A.M. Renner 9430* (holo: NSW1114957; iso: CANB)

Diagnosis: *Genoplesium geminatum* has a distinct aristate petal apex, a feature shared only by *G. mucronatum,* from which *G. geminatum* differs by its obovate rather than oblong labellum shape; by the aristate bract at the base of each flower whose apex lays flush on the flower bud, is longer than the ovary, and is recurved as the flower opens, where as in *G. mucronatum* the bract is shorter than the ovary and has a rounded or obtuse apex; and by the glands of which three are present in the buds of *G. geminatum* but only two in the buds of *G. mucronatum*.

Etymology: from the Latin for doubled and having been united, in reference to the prominent glands on the lateral sepals that form a conspicuous cluster at the apex of the flower buds, which are separated and present only on the lateral sepals at anthesis.

Fig. 5. *Genoplesium geminatum* inflorescence from a plant at the type locality, not vouchered, photo by Brian Towle.

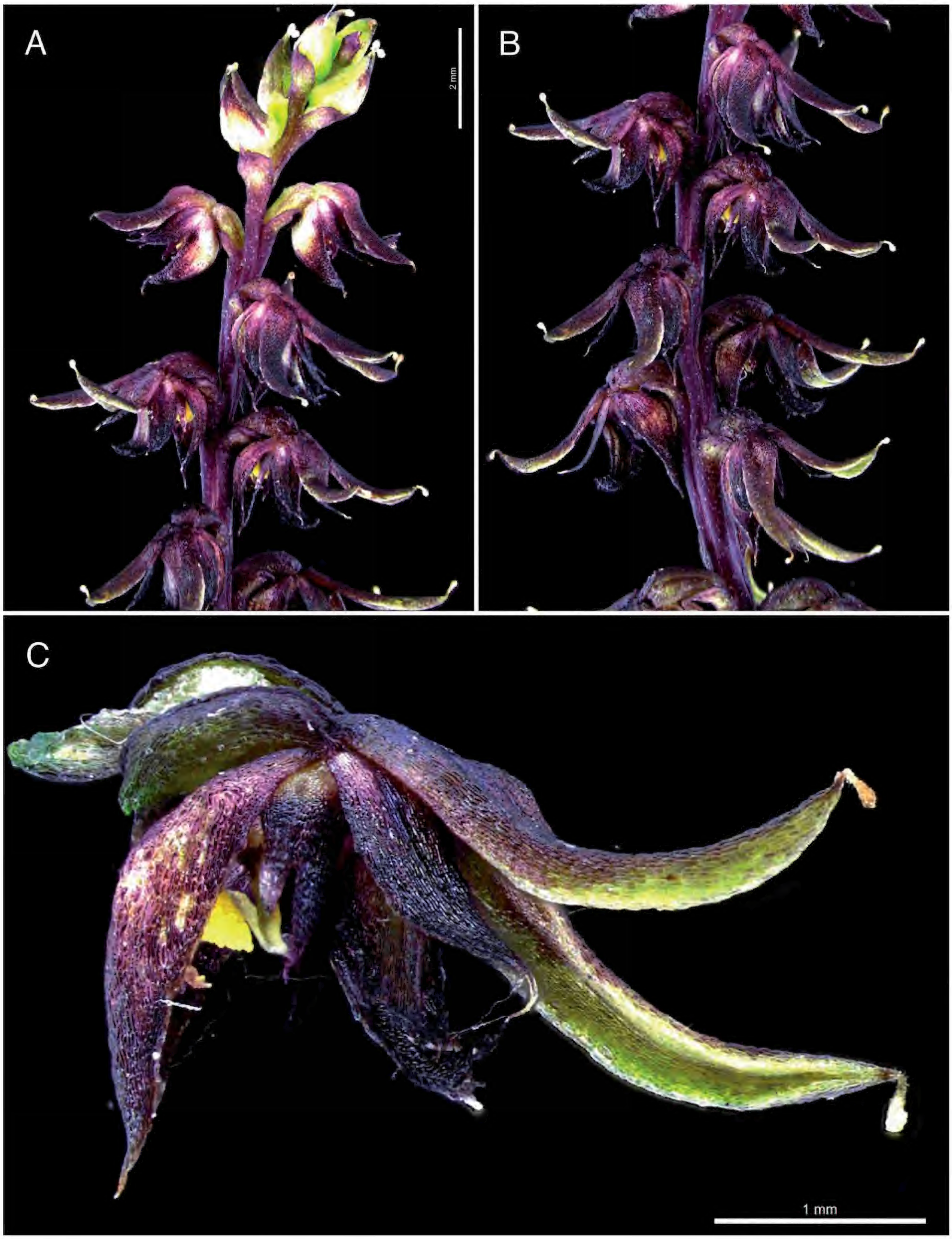

Fig. 6. *Genoplesium geminatum.* A: Upper inflorescence showing buds with close-set glands on lateral sepals, note change in colour of lateral and dorsal sepal with age. B: Middle of inflorescence showing flower spacing and colour, note the contrast between inner and outer lateral sepal surface, and the conspicuous gland at the lateral sepal apex. C. Close-up of flower in lateral-oblique view. All from NSW1114957.

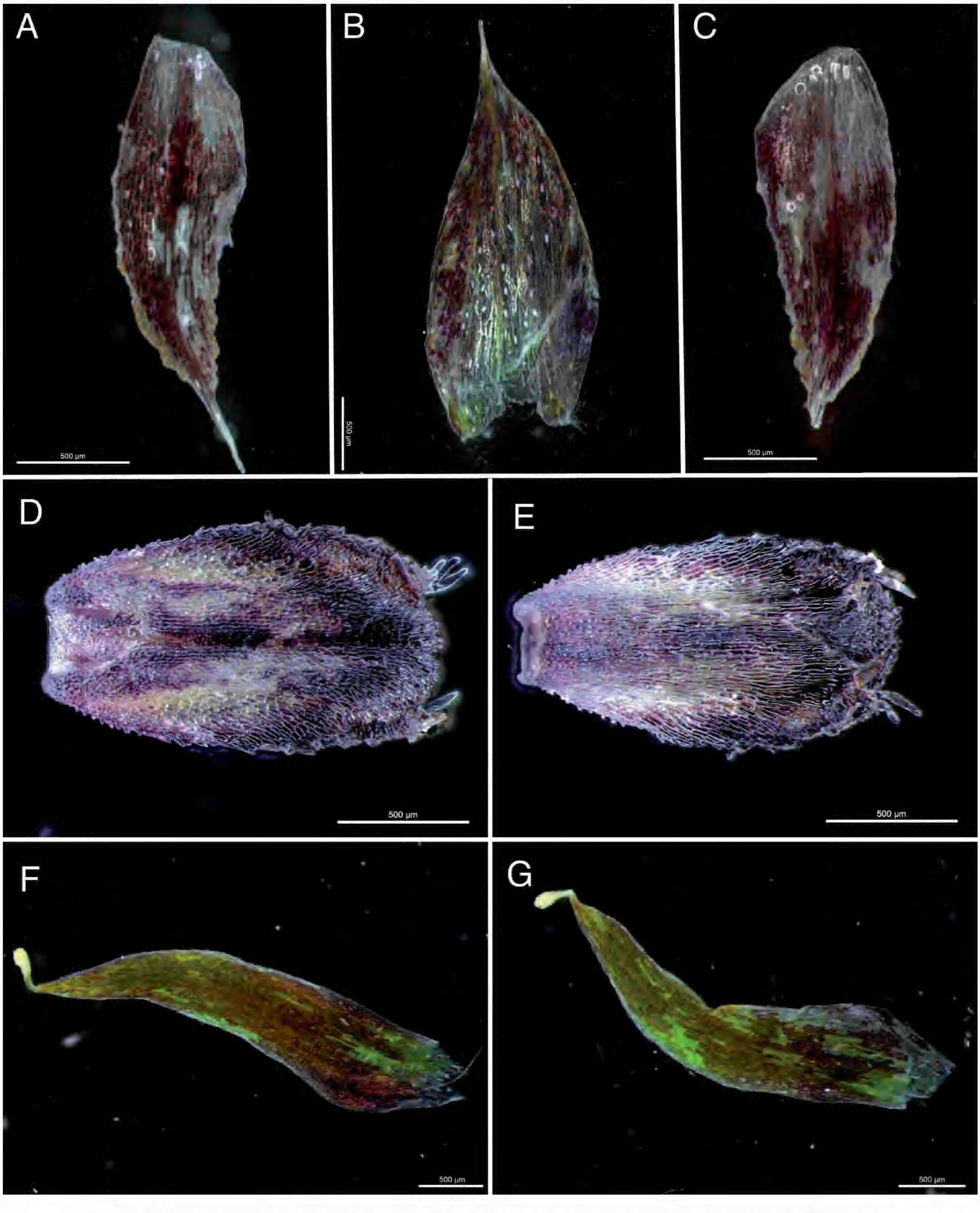

Fig. 7. *Genoplesium geminatum.* A, C: Petals showing apex with hyaline acuminus and margins with irregular crenation. B: Dorsal sepal showing apex with acuminus. D: Labellum in dorsal view showing margins with coarse ciliolate hairs close to the apex. E: Labellum in ventral view showing tapered base, short acuminus at apex, and coarse ciliolate hairs around the apex. F, G: Lateral sepals with the prominent hyaline apical gland. All from NSW1114957.

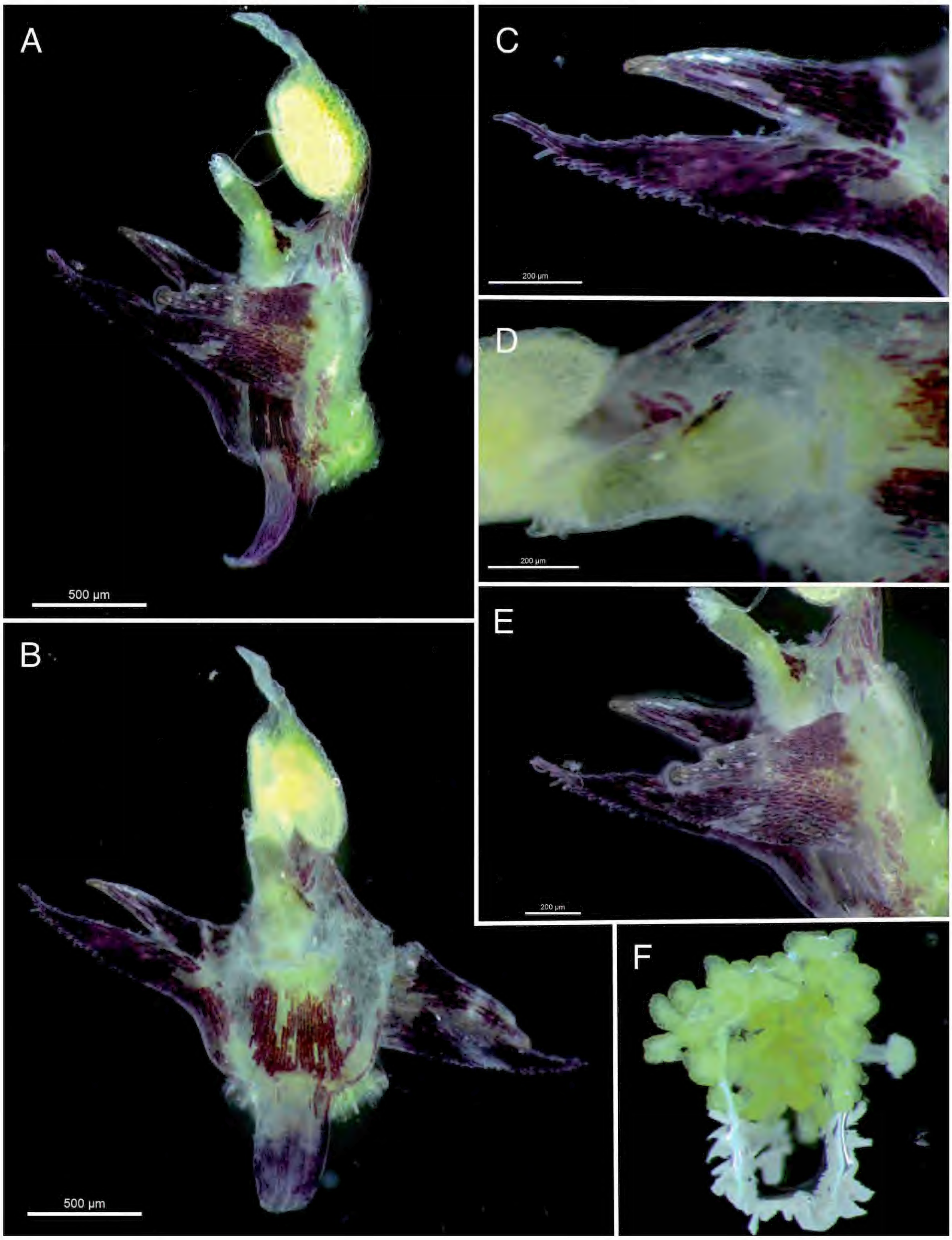

Fig. 8. *Genoplesium geminatum.* A: column in lateral view showing column wings, anther, pollen mass, and column foot, note pigmentation of the column wings. B: Column in frontal view showing the anther, the apical projection of the stigma, the papillate stigma, the two column wings, and the column foot. C: Detail of the column wings. D: The stigma, with papillate surface just visible. E: Column wings and stigma in lateral view. F: Pollinarium. All from NSW1114957.

Leaf terete, to 21 cm long, 1.0 mm wide, lamina sheathing the scape, linear, free lamina 10–15 mm long and 1.5–2.0 mm wide, ending around 15 mm below the first flower. Inflorescence 40–60 mm long, bearing 17–30 flowers on a peduncle 20–30 mm long above the leaf; flowers opening in sequence from the base; pedicel and ovary straight, 1.5–2.5 mm long, lengthening with age such that young spikes with newly opened flowers are densely crowded while older spikes with all flowers open and presenting may be openly spaced. Bracts at the base of each flower 1.5 mm long by 1.0 mm wide, with long apex that lays flush on the flower bud and is recurved as the flower opens. Flowers porrect to deflexed, dorsal sepal 4.0 mm long including apex when flattened, 1.3 mm wide triangular-ovate, concave and inflated at medial base, apex shortly attenuate, bearing a small, obovoid, hyaline, stalked gland in bud, but this gland evidently deciduous and shed as the flower opens, absent at anthesis; lateral sepals 4.0 mm long, 1.0 mm wide, linear-lanceolate, widest just above base, concave toward apex sometimes margins overlapping and so tubular, acute, bearing a hyaline, obovoid, stalked gland; petals 2.3 mm long, 0.9 mm wide, triangular-falcate, outer surface papillate in distal third, dorsal margin straight in lower third, base not ampliate, then curved through 45° to the apex, margin irregularly crenate to shortly ciliolate in distal half, ventral margin curved at base then arched through around 30° from middle to apex, margin irregularly crenate in outer half, apex long attenuate, hyaline, without gland; labellum 2.0 mm long including apex when flattened, 1.0 mm wide, obovate, widest two thirds from the base, apex narrowed with an acute to acuminate apiculus, margins purple, ciliolate from base to apex, toward the base ciliola are short, papilla-like projections, these projections increase in length with increasing distance above the base and around the apex are turgid, non-flexuous, and up to 250 μm long, callus purple, extending from base into the apex, linear except at the very base where broadens to encompass the labellum width, shallowly channelled above a broad depression at the base, channel extending nearly to the apex, cells of the callus arranged in regular longitudinal rows, in contrast to the adjacent labellum lamina where cells are arranged in radiating rows, and are hyaline in the basal half of the labellum and purple in the upper half, callus surface increasingly papillate from the middle of the labellum toward the apex, papillae formed by prorate surface cells, increasing in length toward the apex, where nearly ciliolate across the labellum surface; attachment narrow, articulated, at apex of column foot. Column 2 mm long not including column foot, 0.8 mm wide; column foot present, thin, falcate, purple, 400 μm long; wings purple, unequally bilobed to 0.5 × of their length, upper lobe around 250 μm long and 100 μm wide, ligulate with an asymmetrically acute apex, margins entire, slightly narrower than lower lobe; lower lobe narrow triangular, apex acuminate, margins and surfaces shortly and closely ciliolate; anther versatile, 0.5 mm long, broad elliptic, with a filiform rostrum whose apex is obtuse; stigma a squat lageniform shape, with a long dorsal projection extending well above the column wings in lateral view, the base rounded, surface ciliolate below dorsal projection. Pollinarium comprising a massulate pollen mass adherent to a white, laciniate ring, a short hamulus and small globose viscidium 0.1 mm wide. (Figures 5–8)

Distribution and ecology: *Genoplesium geminatum* has been observed at six locations on the North Coast and Central Coast of New South Wales, from Woodford to the immediate south-west and west of Sydney in the south, to Kearsley, Clarence Town, and Myall Lakes National Park north of Newcastle in the north, in addition to the type locality in the Lake Macquarie area. We estimate the extent of occurrence (EOO) for *G. geminatum* to be 9,086 km^2 and the area of occupancy (AOO) to be 20 km^2. At the type locality, *G. geminatum* grew in gravelly orange-brown clay on the edge of a road corridor amongst short sedges and grasses including *Themeda*.

Recognition: *Genoplesium geminatum* can be distinguished from almost all other *Genoplesium* species by the long acuminate to mucronate tips to the petals. The mucronate petal apex is shared only with ***Genoplesium mucronatum*** (Rupp) M.A.M.Renner, comb. nov. (basionym: *Prasophyllum mucronatum* Rupp., *The Victorian Naturalist* 65(6): 145 (1948)), but sharp petal apices also occur in some other outwardly similar species such as ***Genoplesium laminatum*** (Fitzg.) M.A.M.Renner, comb. nov. (basionym: *Prasophyllum laminatum* Fitzg., *Journal of Botany, British and Foreign* 23: 136 (1885)) and *G. tasmanicum* D.L.Jones. *Genoplesium geminatum* can be distinguished from *G. mucronatum* by the mucronate tip to the floral bract, which is reflexed against the ovary by the opened flower. In *G. mucronatum* the floral bract is shorter than the ovary and has a rounded to obtuse apex (Fig. 9). Other differences between *G. geminatum* and *G. mucronatum* are found in the labellum, which is obovate and has projecting cilia around the apex in *G. geminatum* but broadly oblong without projecting cilia in *G. mucronatum*; and in the glands of which there are usually three in the flower buds of *G. geminatum*, but two in the buds of *G. mucronatum*. The lateral and dorsal sepals of *G. geminatum* generally all bear glands, but the gland on the dorsal sepal is either shed, or grows into an acuminus as flowers develop, so that at anthesis only the lateral sepal glands are present. *Genoplesium mucronatum* (as *Prasophyllum* or *Corunastylis*) is listed as a synonym of *G. rufum* on PlantNet and APNI, but is distinct from this species, as Jones (2021) asserts.

Fig. 9. *Genoplesium mucronatum* inflorescence from a plant from near Appin, not vouchered, photo by Lachlan Copeland, and used with his kind permission.

Genoplesium geminatum differs from *G. laminatum* in its floral bract, which is longer than the ovary, and in generally bearing more flowers on each inflorescence (17–30 versus 5–20), and the labellum margin is ciliate toward the apex, whereas in *G. laminatum* the labellum margin is entire or slightly irregular throughout (Jones 2021).

Genoplesium geminatum has been confused with *G. trifidum* (Rupp) M.A.M.Renner, possibly because the mucronate petal tips may be hyaline and so resemble glands. However, the petal tips of *G. geminatum* are filiform, linear, and seamless with the petal lamina, and in these features differ from the glands at the apex of *G. trifidum* petals, which are circinate to hook-shaped, constricted at their insertion on the petal, and usually presented on the inner surface of the petal. The column arms also serve to differentiate these two species, in *G. geminatum* the upper lobe of the column arm is acuminate, whereas in *G. trifidum* it is rounded, or at most weakly obtuse (see illustration in Renner 2019). The lateral sepal glands in *G. geminatum* are prominent and hyaline, in *G. trifidum* if they are present at all they are small, inconspicuous and orange-pigmented.

Genoplesium geminatum is similar to *G. tasmanicum* but differs by its obovate labellum whose upper margins are shortly ciliate, in *G. tasmanicum* the labellum is ovate to elliptic, and usually broadest below the middle with irregular, rather than ciliate, margins throughout. The flowers of *G. tasmanicum* tend to be more green-pigmented on the outer surface of the lateral sepals than *G. geminatum*, in which the lateral sepal outer surface is uniformly red-purple.

Genoplesium geminatum is similar to *G. rufum* but is readily distinguished by the presence of conspicuous hyaline glands at the apex of the lateral sepals, particularly when flowers are in bud, and by the ciliate upper labellum margins. *Genoplesium rufum* lacks glands on its dorsal and lateral sepals, and has smooth to irregular labellum margins (Jones 2021).

Notes: Illustrated in Jones (2021) as *Corunastylis trifida* (Rupp.) D.L.Jones & M.A.Clem., from plants observed at Clarence Town.

Additional specimens examined: None, unfortunately disruptions caused by COVID-19 prevented us from examining material from other herbaria, including UNE, that may be this species. See under distribution and ecology for additional observations of this species.

Acknowledgements

We thank Lachlan Copeland for sharing distribution records of *Genoplesium geminatum*, and photographs of *G. mucronatum*. We also thank Gordon Deans for first bringing the type location of *Genoplesium geminatum* to our attention. We thank Lachlan Copeland and an anonymous reviewer for comments that improved the manuscript.

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Vaccinium (Ericaceae) in Sulawesi: a new species and a list of known taxa

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Abstract

Vaccinium sulawesiense Mustaqim & P.W.Fritsch, a newly discovered species endemic to Sulawesi, Indonesia, is described. This species is similar to *V. simulans* Sleumer but differs in having an acuminate leaf apex, larger floral organs, and an absence of trichomes in the upper half of the inner surface of corolla and disk. This species is known from two specimens, one from a mid-montane rainforest in Mamasa Regency, Sulawesi Barat Province, and the other from Poso Regency, Sulawesi Tengah Province. An updated list of the 17 known *Vaccinium* species in Sulawesi is also provided.

Introduction

The Ericaceae of Sulawesi have been treated in *Flora Malesiana* (Sleumer 1964, 1966–1967) but many new taxa have been subsequently described (e.g. Argent 2009, 2014; Craven 2014; Argent & Widjaja 2015; Argent & Mambrasar 2019; Mustaqim & Ardi 2019, 2021; Hutabarat *et al.* 2022). Five genera of Ericaceae occur in Sulawesi: *Gaultheria* Kalm ex L., *Rhododendron* L., *Rigiolepis* Hook.f., *Styphelia* Sm., and *Vaccinium* L. (Chase *et al.* 2016; Argent 2019; Kron *et al.* 2020; Mustaqim & Ardi 2021).

Sixteen species and two varieties of *Vaccinium* (tribe Vaccinieae) are currently recognized from Sulawesi and most are endemic (Sleumer 1961, 1966–1967; Argent 2019; Mustaqim & Ardi 2019). The main taxonomic reference for the genus is still the account in *Flora Malesiana* (Sleumer 1966–1967) and since that publication, no substantial taxonomic work on the *Vaccinium* of Sulawesi has been published. In the early 2000s, *Vaccinium* was included in a checklist of woody plants from Sulawesi (Kessler *et al.* 2002) but only 12 species were listed, fewer than in Sleumer (1966–1967) with several species apparently inadvertently excluded. In 2019, one

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species was transferred into the recently resurrected genus *Rigiolepis*, *R. henrici* (J.J.Sm.) Argent, an endemic of South Sulawesi Province (Argent 2019). The latest taxon described from the island since *Flora Malesiana* is *Vaccinium paludicola* Sleumer var. *hirsutulum* Mustaqim (Mustaqim & Ardi 2019).

During fieldwork conducted in November and December 2019 in the mountainous regions of Mamasa Regency, Sulawesi Barat Province, the first and the fifth authors collected an unusual specimen of *Vaccinium*. Later, a morphologically similar specimen was collected by the fourth author from Mount Rorekatimbu, Sulawesi Tengah Province. After detailed examination of these specimens and in consultation with the relevant literature and type material, we concluded that the specimens represent a species new to science, which we describe herein. To facilitate taxonomic understanding of *Vaccinium* in Sulawesi, we also provide an updated checklist of the known species and varieties of *Vaccinium* from the island.

Material and Methods

Herbarium specimens were prepared as in Bridson and Forman (1992). Flowers were preserved in 70% ethanol and used for the description. Overall morphology was compared with other species in relevant literature (Sleumer 1966–1967; Vander Kloet 2005; Argent 2019; Mustaqim & Ardi 2019), herbarium material from CEB, and online images of type specimens available from Naturalis Biodiversity Center Leiden (http://bioportal.naturalis.nl), Kew Herbarium Catalogue (http://apps.kew.org/herbcat), and JSTOR Global Plants (http://plants.jstor.org). Preliminary conservation status was evaluated in accordance with the IUCN Standards and Petitions Subcommittee (2022). The Extent of Occurrence (EOO) and Area of Occupancy (AOO) were analysed with GeoCAT (www.geocat.kew.org) (Bachman *et al.* 2011). The checklist was based on the same literature, herbarium, and online sources as above. The map used in this study was prepared with SimpleMappr (Shorthouse 2010).

Taxonomy

Vaccinium sulawesiense Mustaqim & P.W.Fritsch, ***sp. nov.***

Type: Indonesia: Sulawesi Barat Province: Sulawesi Island, Mamasa Regency, trail to Talambai Village, 1890 m asl, 25 November 2019, *W.H. Ardi et al. 583* (holo: BO; iso: FIPIA).

Small tree, terrestrial, evergreen, to 5 m tall. Young branchlets slightly flexuous at apex, terete, sometimes slightly angular, 1.5–3.5 mm wide, with sparse minute ferruginous, simple trichomes near leaf insertion at early stage, very soon glabrous; mature branchlets lenticellate, bark not peeling. Perennating buds monomorphic, one per leaf axil, depressed-globose, up to 1.5 × 2.5 mm, with multiple overlapping scales, scales rounded at apex, glabrous. *Leaves*: spirally arranged, sparse; petiole circular, channelled above, light green tinged with red, 6.5–10.0 × 1.3–1.5 mm, glabrous; blade elliptic or slightly ovate, 65–80 × 23–30 mm, coriaceous; reddish on both surfaces when young, green adaxially, pale whitish abaxially; adaxially initially covered with reddish and curly minute ferruginous trichomes adaxially, also a few surrounding base, glabrescent, abaxially nearly glabrous, glabrescent; base attenuate, margin with 2(–3) pairs of basal glands, lower pair of marginal glands at 2–3 mm below leaf blade and petiole junction, upper pair 2–5 mm above the leaf blade and petiole junction with the distances varying among each pair, once observed right at the point of junction, distal glands appearing only as remote minute crenations, slightly recurved, apex acuminate, gland-tipped, midvein raised abaxially, slightly impressed or nearly flat adaxially, secondary veins 4 on each side of midvein, basal most vein short and close to margin with 1 or 2 usually arising from base, others from midvein, slightly raised or flat but distinct above, raised beneath, tertiary veins distinct and slightly raised abaxially, obscure adaxially. *Inflorescences*: axillary, those from uppermost node appearing terminal, racemose, 1 per leaf axil, 7–10-flowered; peduncle stout, 3–5 mm long; rachis stout and fleshy *in vivo*, angular, 20–35 mm long, glabrous; bracts not seen, presumably early caducous. *Pedicels* terete, 7–10 mm long, 1 mm wide at base, widening to c. 1.3 mm at apex, glabrous except for a few trichomes at the very tip, bracteoles absent. *Flowers*: articulated with pedicels. *Hypanthium* campanulate or turbinate, 3–4 × 5–6 mm, sparsely to sub-densely appressed-glandular-pubescent; calyx limb 2.5–3.3 mm long, glabrous, lobes broadly deltoid, 1.3–2.5 × 2.8–3.5 mm, glabrous, margin densely ciliate, without sessile marginal glands, apex obtuse to subrounded, the very tip with a minute gland. *Corolla*: in bud ovoid-cylindric, at anthesis pale red with whitish base, urceolate-elliptic, distinctly 5-angled, bluntly 5-angled at base, angles sharper distally, 13.5–15.5 × 7.0–8.8 mm, glabrous outside, pubescent on lower half inside; corolla lobes 5, becoming reflexed, ovate, c. 1.5 × 2.8 mm, apex obtuse. *Stamens*: 10, distinct, uniform in shape, 7.2–7.5 mm long; filaments 3.0–3.6 mm long, basally dilated and tapered from base to apex, pubescent except at base and apex; anthers echinulate, 2.6–3.0 mm long, cells c. 1.4–1.8 mm long, dorsally with two spurs; tubules parallel, cylindrical, subequal to slightly narrower than cells, 1.3–1.6 mm long, with several

apically stipitate-glandular trichomes, gland heads ± globose, pore slightly larger than tubule, with glandular teeth at apex; dorsal spur oriented slightly to rather distinctly upcurved, c. 0.5 mm long. *Ovary*: glabrous, 5-locular, appearing pseudo-10-locular with false partitions extending 0.4–0.5 mm from inner wall; ovules in two columns; disk annular, c. 0.9 mm high, apex rounded, glabrous. *Style*: shorter than corolla tube, 11–12 mm long, pubescent except within upper third. *Fruit*: not seen. (Fig. 1).

Fig. 1. Morphology of *Vaccinium sulawesiense* Mustaqim & P.W.Fritsch: A. Living plant. B. Branchlets with leaves and inflorescences. C. Inflorescence. D. Flowers. E. Longitudinal section of flower. F. Stamens. G. Cross-section of ovary. Scale bar: B–D = 10 mm; E = 5 mm; F–G = 1 mm. Photographs: A–C by Wendy A. Mustaqim, E–G by Wisnu H. Ardi. All images from *W.H. Ardi et al. 583*.

Diagnostic characters: *Vaccinium sulawesiense* is similar to *V. simulans* Sleumer but differs in having an acuminate leaf apex (*vs* broadly attenuate to rounded), larger corolla (13.5–15.5 × 7–8.8 mm *vs* 4–5 × 2.5 mm), a glabrous disk (*vs* pubescent), longer filaments (3–3.5 mm *vs* 1.8 mm), longer anther cells (1.3–1.8 mm *vs* 0.6 mm), longer anther tubules (1.3–1.6 mm *vs* 0.5 mm), and a longer style (11–12 mm *vs* 4 mm) bearing trichomes near the apex (*vs* restricted to the lower half).

Etymology: The specific epithet refers to the island of Sulawesi.

Distribution: Endemic to Sulawesi: known from Sulawesi Tengah and Barat Province (Fig. 2).

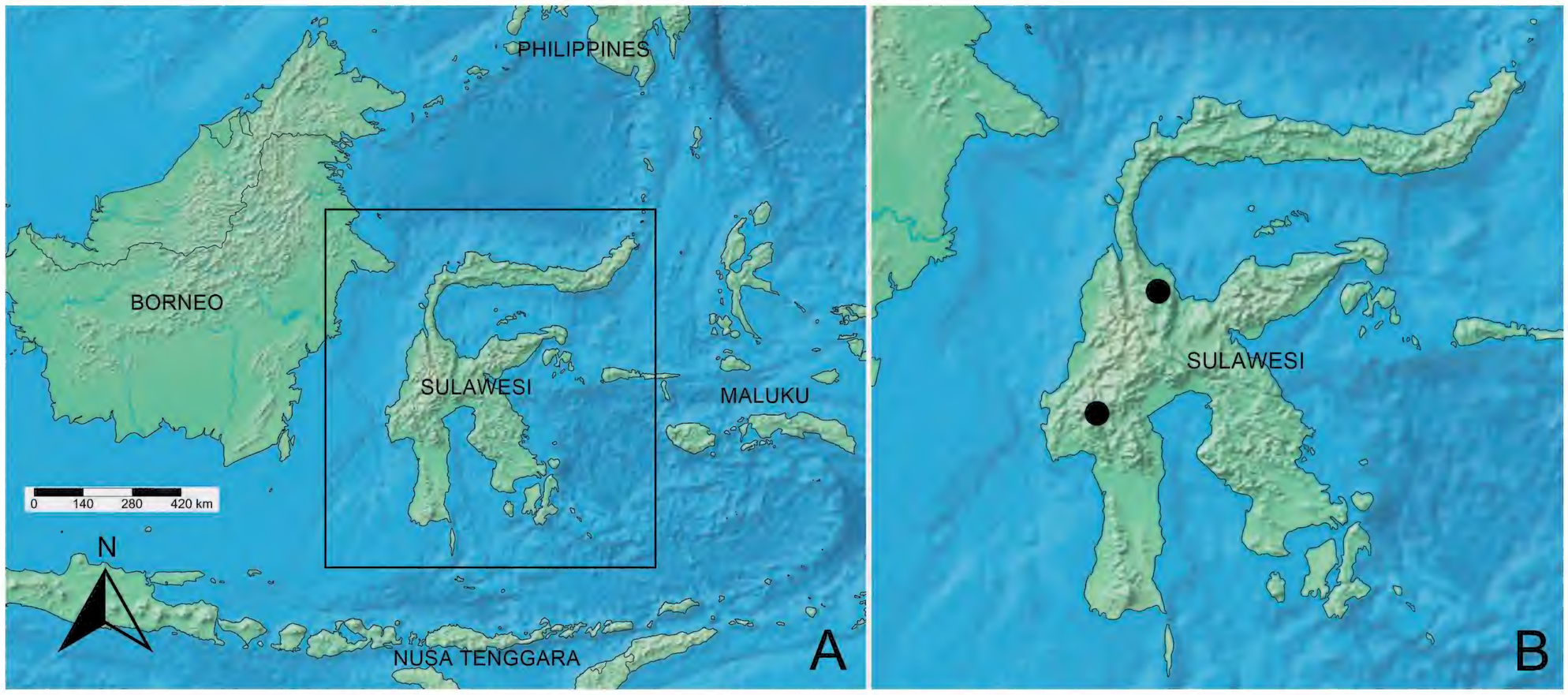

Fig. 2. Geographic distributions of *Vaccinium sulawesiense* Mustaqim & P.W.Fritsch: A. Eastern Indonesian Archipelago showing Sulawesi (box). B. The distribution of *V. sulawesiense* across Sulawesi (●).

Habitat and ecology: The species was found growing on mid- to upper montane forests at 1890 to c. 2250 m asl. In Mamasa Regency, some species recorded in its habitat are *Gaultheria retusa* (Sleumer) Kron & P.W.Fritsch, *Ficus oleifolia* King, several shrubby *Schefflera* J.R.Forst. & G.Forst., and other species of *Vaccinium* such as *V. myrtoides* (Blume) Miq.

Preliminary IUCN Red List conservation status: This species is only known from two locations. In Mamasa, our survey along trails in surrounding areas within 5–10 km yielded only one individual, whereas in Mt Rorekatimbu so far it is known only from one location; therefore, this species has an AOO of 8 km^2. With the currently available data, we recommend the Data Deficient (DD) category until further data become available. However, the location of the type is threatened by habitat conversion for agriculture, and once further data are available, a threatened category may be justified.

Notes: The new species can be placed in *Vaccinium* section *Bracteata* Nakai sensu Sleumer (1966–1967) in having many-flowered racemes, calyx lobes that are shorter than the calyx tube, a shallowly lobed corolla with an urceolate- to ellipsoid-cylindrical corolla tube, and anther tubules opening by a terminal large pore. *Vaccinium* section *Bracteata* is the only section that occurs in Sulawesi after the resurrection of the genus *Rigiolepis*, formerly known as *Vaccinium* sect. *Rigiolepis* (Hook.f.) Sleumer, with one species in Sulawesi, *R. henrici* (Sleumer) Argent (Sleumer 1966–1967; Argent 2019). *Vaccinium sulawesiense* keys out in the Flora Malesiana to *V.* section *Bracteata* (Sleumer 1966–1967) as *V. simulans* Sleumer, a species endemic to Sabah state, Malaysia in northern Borneo (Sleumer 1966–1967; POWO 2022).

In the key to Bornean *Vaccinium* in Argent (2019), this species also keys best to *V. simulans* by its erect shrub habit, young stems early glabrescent, with a few short glandular trichomes near the petiole insertion, prominent vegetative buds that are spherical, blunt and 2.5 mm wide, leaves with a petiole ≤ 10 mm long, and leaf blades > 15 mm and ≤ 30 mm wide with attenuated base and adaxial midvein flat in the proximal half. The only character that does not match is the raised abaxial lateral veins, which are instead obscure in *V. simulans*. The raised abaxial lateral nerves are found in one of the most morphologically similar species to *V. simulans*, i.e. *V. claoxylon* J.J.Sm. However, *V. claoxylon* has a raised adaxial leaf blade midvein in the proximal half, a character not present in *V. sulawesiense*. *Vaccinium claoxylon* also differs from *V. sulawesiense* by larger leaf blades (70–140 × 40–60 mm *vs* 65–80 × 23–30 mm), shorter pedicels (1–2 mm *vs* 7–10 mm long), bracteoles

present (*vs* absent), smaller corolla (6–8 × 2.5 mm vs 13.5–15.5 × 7–8.8 mm), and shorter stamens (c. 4 mm *vs* 6–7 mm). Like *V. simulans*, *V. claoxylon* is endemic to Borneo but has a wider geographical range from Sabah (Kinabalu) and Kalimantan (Kalimantan Barat and Kalimantan Timur Province) (Sleumer 1961).

According to Sleumer (1966–1967), the *Vaccinium* species of Sulawesi that is most similar to the new species is *V. latissimum* J.J.Sm., a species of Mamasa Regency as well as other areas in Sulawesi Tengah and Selatan Provinces. Both species have presumably small and early caducous bracts and distinct anther spurs. However, *V. latissimum* differs from *V. sulawesiense* by larger leaf blades (90–130 × 50–100 mm *vs* 65–80 × 23–30 mm) that are suborbicular or broadly elliptic (*vs* elliptic or slightly ovate) with apices mostly rounded or only short- or apiculate-acuminate (*vs* distinctly acuminate) and with more lateral nerves (6–7 *vs* 4 pairs), a deeply lobed corolla (*vs* shallowly lobed) with lobes erect or nearly so (*vs* reflexed), the absence of glandular trichomes on the anthers (*vs* present), and a glabrous style.

Sleumer (1966–1967) listed 17 species of *Vaccinium* for Sulawesi, but one of them was recently transferred to *Rigiolepis* (i.e., *R. henrici*) (Argent 2019). The discovery of *V. sulawesiense* increases the number of *Vaccinium* species known for Sulawesi to 17 species. Some unidentified Sulawesi specimens were listed by Kessler *et al.* (2002) and some of these may represent undescribed species in need of further study.

Additional specimen examined: INDONESIA: Sulawesi Tengah Province: Sulawesi Island, Poso Regency, Lore Utara, Mount Rorekatimbu, c. 2250 m, 14 Aug 2021, *F.S. Lakiu s.n.* (CEB!).

An updated list of *Vaccinium* taxa in Sulawesi

1. ***Vaccinium apophysatum*** Sleumer, *Blumea* 11: 82 (1961)[1]

   Note. Sleumer (1966–1967) indicates that this species is endemic to the 'N. Moluccas (Talaud Is.: E. slope of Mt Piapi on Karakelang)'. The Talaud Islands are best considered a part of Sulawesi rather than the Moluccas (Cannon *et al.* 2007; Thomas *et al.* 2013–onwards); thus the species is listed here, as in Kessler *et al.* (2002).

2. ***Vaccinium aucupis*** Sleumer, *Bot. Jahrb. Syst.* 71: 160 (1940)[1]
3. ***Vaccinium centrocelebicum*** Sleumer, *Blumea* 11: 45 (1961)[1]
   - var. ***centrocelebicum***[1]
   - var. ***majus*** Sleumer, *Blumea* 11: 46 (1961)[1]
4. ***Vaccinium contractum*** Sleumer, *Bot. Jahrb. Syst.* 71: 160 (1940)[1]
5. ***Vaccinium cuneifolium*** (Blume) Miq., *Fl. Ned. Ind.* 2: 1062 (1859)[1]
6. ***Vaccinium dubiosum*** J.J.Sm., *Bot. Jahrb. Syst.* 68: 214 (1937)[1]
7. ***Vaccinium kjellbergii*** J.J.Sm., *Bot. Jahrb. Syst.* 68: 211 (1937)[1]
8. ***Vaccinium latissimum*** J.J.Sm., *Bull. Jard. Bot. Buitenzorg*, sér. 3, 1: 409 (1920)[1]
9. ***Vaccinium lucidum*** (Blume) Miq., *Fl. Ned. Ind.* 2: 1061 (1859)[2]
10. ***Vaccinium myrtoides*** (Blume) Miq., *Fl. Ned. Ind.* 2: 1062 (1859)[2]
11. ***Vaccinium paludicola*** Sleumer, *Blumea* 11: 53 (1961)[1]
    - var. ***paludicola***[1]
    - var. ***hirsutulum*** Mustaqim, *Telopea* 22: 201 (2019)[1]
12. ***Vaccinium pilosilobum*** J.J.Sm., *Bot. Jahrb. Syst.* 68: 213 (1937)[1,2]
13. ***Vaccinium sclerophyllum*** Sleumer, *Blumea* 11: 96 (1961)[1]
14. ***Vaccinium sulawesiense*** Mustaqim & P.W.Fritsch, this publication[1]
15. ***Vaccinium timorense*** Fawc. in H.O.Forbes, *Naturalist's Wanderings E. Archipel.*: 509 (1885)[2]
16. ***Vaccinium tomicipes*** J.J.Sm., *Bot. Jahrb. Syst.* 68: 212 (1937)[1]
17. ***Vaccinium warburgii*** Sleumer, *Bot. Jahrb. Syst.* 71: 167 (1940).[1]

[1]Endemic; [2]Not listed in Kessler *et al.* (2002) but documented from Sulawesi in Sleumer (1966–1967).

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Grevillea tesselata Olde (Proteaceae: Grevilleoideae: Hakeinae), a rare new species of uncertain affinity from the Avon Wheatbelt region of south-west Western Australia

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Abstract

Grevillea tesselata Olde is described here as a new species from south-west Western Australia, known only from a small population in a fragmented roadside landscape, and previously recognised under the phrase name *Grevillea* sp. Trayning (W. Johnston WJ 071). Following the *Flora of Australia*, the new species keys to the *Grevillea Acacioides* Group which comprises only three species, *G. endlicheriana* Meisn., *G. acacioides* C.A.Gardner ex McGill. and *G. gordoniana* C.A.Gardner. A binary assessment of 50 morphological characters presented here supports the view that *G. acacioides* and *G. endlicheriana* are sister species. A key to the new species is provided and its distribution updated. *Grevillea tesselata* has a Priority One Conservation Code according to the Western Australian Herbarium.

Introduction

An unusual *Grevillea* was first collected in the Trayning area in the Avon Wheatbelt region of south-west Western Australia (*W. Johnston WJ 071*, PERTH) in December 2006. The collection was subsequently recognised as a distinct taxon under the phrase name *Grevillea* sp. Trayning (W. Johnston WJ 071) by Mike Hislop and bought to the attention of the author. Subsequent searches have made additional collections from the original locality, but not located any additional populations. The author has been investigating a significant number of *Grevillea* populations in southern Western Australia that do not readily conform to recognised species (Olde 2020, 2021a–c, 2022; Olde & Marriott 2021; Olde & Keighery 2022), and as part of this work, *Grevillea* sp. Trayning (W. Johnston WJ 071) is here described as a new species, *Grevillea tesselata* Olde. The new species keys to the Acacioides group of *Flora of Australia* (Makinson 2000), so its relationships are considered relative to this group.

McGillivray and Makinson (1993: 382) first treated *Grevillea endlicheriana* Meisn., *G. acacioides* C.A.Gardner ex McGill. and *G. gordoniana* C.A.Gardner as an informal group because they share isobilateral or terete leaves, a spongy pericarp that tightly encloses the seed, and winged seeds. The same species were similarly grouped together in the key by Olde and Marriott (1994), and then informally identified as the '*Acacioides* Group' by Makinson (2000). However, after sampling two out of these three species (*G. endlicheriana* and

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G. gordoniana), a phylogenetic analysis using four plastid and one nuclear DNA regions identified that the Group was polyphyletic (Mast *et al.* 2015). A closer examination by the authors of that study identified that three morphological character states of *G. endlicheriana* were shared by *G. acacioides*, which was not included in the study, but not shared by the distantly related *G. gordoniana*. These are: retrorse ovaries, a spongy pericarp that tightly encloses the seed, and mature fruits with a persistent dorsal ridge of gynoecial tissue remaining fully or partially excurrent.

These results suggest that the relationship between *Grevillea endlicheriana* and the new species recognised here, *G. tesselata*, also requires investigation. As the new species was not included in the molecular study of Mast *et al.* (2015), the relationship between this new taxon and the group is further explored here using analysis of morphological data based on characters considered diagnostic for species in this group.

Materials and methods

The four-species 'Group' was examined here by a binary assessment of morphological similarity (The Simple Matching Distance *sensu* Sneath and Sokal 1973), to determine whether the new species should be included in the *Acacioides* Group. A matrix of asymmetric attributes in which 0 is more important than 1 was established (Table 1) based on the descriptions of *G. endlicheriana* (and *G. filifolia* Meisn.) provided by Meisner (1845: 546–547), Bentham (1870: 474), McGillivray and Makinson (1993: 385), Olde and Marriott (1995a: 143–145) and Makinson (2000: 189), a study of herbarium specimens at NSW and PERTH, a study of plants in the wild, and experience with cultivated plants over several decades. Morphological characters in the descriptions considered important to each species' concept were identified and 50 were listed individually for comparison. The characters defining *G. endlicheriana* were all allotted a score of 0 at the appropriate coordinate. Similarity of this attribute in the other three species was also scored with 0. Differences were scored as 1. Characters shared by all species were eliminated as uninformative. Overall similarity was then assessed by comparing the number of shared derived character states for each species. The criterion for similarity and hence inferred close relationship (the highest score) was arbitrarily determined as a Distance Coefficient of > 0.75, which allowed for a moderately large number of potential autapomorphies in the species examined.

Results and conclusions

The distance coefficient for both *G. tesselata* and *G. gordoniana* was assessed as too low to meet the similarity criterion. This is consistent with the published phylogenetic analysis of subtribe Hakeinae Endl. that resolved *G. gordoniana* as part of separate clade, rather than as sister to *G. endlicheriana* (Mast *et al.* 2015).

Table 1. Matrix of asymmetric morphological attributes in the *Grevillea* Acacioides Group for assessment of relationships in which 0 is weighted as more important than 1.

Attribute	Character	Scoring	Species			
			endlicheriana	*acacioides*	*tesselata*	*gordoniana*
habit	regeneration modes	resprout = 0; non-resprout = 1	0	0	1	1
branchlets	shape	angular = 0; round = 1	0	1	1	1
leaves	division	always simple = 0; sometimes divided = 1	0	0	1	1
	ribbing	with ribs = 0; smooth = 1	0	0	1	1
	type	similifacial = 0, not = 1	0	1	1	1
	apices	non-pungent = 0; pungent = 1	0	1	1	1
conflorescence	development	basipetal = 0; acropetal = 1	0	0	1	0
	aggregation	multi-branched = 0; simple–2-branched = 1	0	1	1	0
	prominence	emergent = 0; enclosed = 1	0	1	1	0
peduncle	colour	not rusty = 0; rusty =1	0	0	1	1
	presence	present = 0; absent to very short = 1	0	1	0	0
rachis	cf. peduncle	concolorous = 0; discolorous = 1	0	0	1	0
common bracts	type	fleshy = 0; papery=1	0	0	0	1
	prominence	inconspicuous = 0; conspicuous = 1	0	1	0	1

Attribute	**Character**	**Scoring**	**Species**			
			endlicheriana	*acacioides*	*tesselata*	*gordoniana*
pedicels	indumentum	glabrous = 0; hairy = 1	0	0	1	0
torus	shape (in polar view)	regular = 0; not regular = 1	0	0	1	0
	width	< 1.4 mm = 0; >1.4 mm = 1	0	0	1	1
nectary	visibility above toral rim	prominent = 0; obscure =1	0	0	1	1
	shape	semi-annular = 0; long U-shape = 1	0	0	1	1
	margin	toothed = 0; smooth=1	0	0	1	1
pistil	length	< 13 mm = 0; > 13 mm = 1	0	0	1	1
gynophore	length at anthesis	< 2 mm long = 0; > 2 mm = 1	0	0	1	1
	insertion	vertical = 0; oblique = 1,	0	0	1	1
carpel	orientation	retrorse = 0; not retrorse = 1	0	0	1	1
style	papillae	usually present = 0; never present = 1	0	0	1	0
pollen-presenter	shape	round = 0; not round = 1	0	0	1	1
	obliquity	>45° = 0; <45° = 1	0	1	0	1
perianth	abaxial surface	glabrous = 0; hairy =1	0	0	1	0
	hairs on adaxial surface condensed into a beard	yes = 0; no = 1	0	0	1	0
tepals	tepal-limbs	mid-line ribbed = 0; not midline ribbed = 1	0	0	1	1
fruit	gynoecial tissue	partly excurrent = 0; not excurrent = 1	0	0	1	1
	lateral compression	uncompressed = 0; noticeably compressed = 1	0	1	0	0
	persistence	quickly deciduous = 0; persistent = 1	0	0	1	1
	usual colour	anthocyanins present = 0; never = 1	0	1	1	1
	dorsal shape	concave = 0; straight =1	0	0	1	1
	attachment	lateral on dorsal side = 0; basifixed = 1	0	0	1	1
	shape	obloid-ventricose = 0; other = 1	0	0	0	1
	glandular exudate	absent = 0; present = 1	0	1	0	1
	pericarp surface	not ridged = 0; transversely ridged = 1	0	1	0	0
follicular valves	discoherence at anthesis	fully discoherent = 0; along the ventral suture only = 1	0	0	1	1
	detachment	differential = 0; conjoined = 1	0	0	1	1
mesocarp	texture	foveolate = 0; crustaceous = 1	0	0	1	1
	shape of seed cavity	different to pericarp = 0; same as pericarp = 1	0	0	1	1
	thickening	marked = 0; moderate = 1	0	0	1	1
	transverse sub-basal funicular groove	present = 0; absent = 1	0	0	1	1
endocarp	texture	smooth = 0; flaky = 1	0	0	1	0
seed	adaxial surface	channelled with raised lateral borders = 0; not channelled = 1	0	0	1	0
	exposure of adaxial surface	partly hidden by border = 0; fully exposed = 1	0	0	1	0
	shape	linear-oblong = 0; obovoid = 1	0	0	1	0
	enclosure	tightly enclosed = 0; not tightly enclosed = 1	0	0	1	1
		Unshared characters		12	42	34

Grevillea acacioides shared 38 of the 50 scored characters with *G. endlicheriana,* a distance coefficient (d) of 0.76, whereas *G. gordoniana* shared 16 (d = 0.32) and *G. tesselata* only 9 (d = 0.18). The high level of overall morphological similarity between *G. acacioides* and *G. endlicheriana*, indicates a close relationship and is consistent with results found by Mast *et al.* (2015). The numerical results justify continued recognition of the '*Acacioides*' Group with membership reduced to two species, *G. acacioides* and *G. endlicheriana*, at least until more information can be obtained on their relationships. In this analysis, *G. tesselata* had the lowest score of morphological similarity. Since Mast *et al.* (2015) resolved *G. gordoniana* in a clade separate from *G. endlicheriana*, it seems reasonable that *G. tesselata* should likewise be excluded until results of a whole of genus molecular phylogeny is produced. This analysis does not exclude or confirm a close relationship between *G. gordoniana* and *G. tesselata*. Accordingly, *G. tesselata,* which had the lowest distance co-efficient relative to *G. endlicheriana*, is here treated as a species of uncertain affinity.

Revised Key to Groups

Amendments to the Key to Groups and the Key to Species *sensu* Olde and Marriott (1994: 189–221) are given here.

29 Nectary prominent, semi-annular with recurved margin, not adnate to the inner face of the torus; torus not invaginated; ovary retrorse; fruits with axial gynoecial tissue wholly or partly excurrent over its entire length; fruit attachment dorsal; leaves simple..... Group 17 (*Acacioides* Group)

29* Nectary obscure, long U- or V-shaped, adnate to the inner face of the torus; torus invaginated; ovary not retrorse; fruits with axial gynoecial tissue partly concurrent; fruit attachment basal; leaves simple and divided

29A Leaves terete

29B Leaves without grooves on adaxial surface; conflorescences multi-branched, emergent, imbricate; fruits obloid-sigmoid and string bean-like, the exocarp viscid, with resinous exudate; pedicels and perianth glabrous outside ..... Group 17a (*G. gordoniana*)

29B* Leaves 1-grooved on the adaxial surface; conflorescences simple to 1-branched, enclosed, not imbricate; fruits ellipsoid, the exocarp shiny non viscid, ultimately tessellated; pedicels and perianth sparsely hairy outside..... Group 17b (*G. tesselata)*

29A* Leaves not terete

Taxonomy

Grevillea tesselata Olde, **sp. nov.**

Type: Western Australia: [precise locality withheld], W of Trayning. 31°1'20.5"S, 117°37'53.3"E, GDA 94, *M. Hislop* 3743, 15 Dec 2007 (*holo*: PERTH 07695667; *iso*: AD, CANB, K, MEL, NSW 536134).

Grevillea sp. Trayning (W. Johnston WJ 071), Western Australian Herbarium (1998 onwards), https://florabase.dpaw.wa.gov.au/browse/profile/31212 (accessed 2 May 2022)

Bushy, seed-obligate, weakly serotinous *shrubs* 2–2.5 m high, 3–4 m wide; branches ascending to spreading. *Branchlets* erect to slightly spreading, slightly flexuous, often forked distally, terete, densely sericeous, the hairs *c.* 0.25 mm long, biramous with mostly ferruginous contents. *Leaves* (30–)45–105 mm long, (1.1–)1.3–1.5 mm diameter, erect to ascending, sessile to shortly petiolate, simple, rarely bipartite with secondary bipartite division of one lobe, subterete to slightly compressed laterally, most slightly incurved, some straight, not crowded, concolorous, the surface smooth except for a medially grooved longitudinal rib on the adaxial side, sometimes also shallowly channelled on either or both sides of the rib, the surface with irregular longitudinal wrinkling when dry, the wrinkles not formed into a continuous rib; *petioles* scarcely distinguishable; *base* narrowly attenuate; *apex* acute, terminated by a necrotic, straight or slightly curved, pungent spine 1.25–1.5(–2.8) mm long; surface of young leaves with a dense ferruginous indumentum of appressed, short trichomes *c.* 0.05 mm long, of mature leaves the hairs white, mostly evanescent, appressed, the surface soon glabrous, the hairs mostly *c.* 0.2 mm long, biramous, appressed, minute hairs not evident; *venation* obscure; *texture* stiffly coriaceous. *Conflorescences* acropetal, terminal or subterminal on short branches, simple or 1-branched, pedunculate, enclosed within the foliage; *simple conflorescences* erect, regular, subglobose to umbelloid, 20–30-flowered; *conflorescence buds* 3 mm long, 2.25 mm wide, ovoid, not imbricate; *peduncles* (5–)8–10 mm

long, ferrugineus-sericeous, usually with one or two bud-like outgrowths above the distal leaf; *inflorescence rachis* 8–12 mm long, 0.8 mm thick, white-sericeous, the hairs biramous; rachis extension 0.5–1 mm long, oblique, triangular or sometimes withered, subcaudate; *peduncular bracts* (when present) solitary, 3 mm long, *c*. 1–1.5 mm wide, oblong-cymbiform, apiculate; *involucral bracts* 2–2.5 mm long, 2 mm wide, ovate-apiculate, the abaxial surface rusty-sericeous with prominent raised central rib, some hairs glandular and with minute resinous deposits evident; *common bracts c*. 1.5 mm long, 1 mm wide, ovate to obovate or elliptical, apiculate, the abaxial surface sparsely white-sericeous, soon glabrous-ciliate, caducous when buds are *c*. 1.25 mm long; *bractiform leaves* 2.5 mm long 1.75–2 mm wide at base, ovate apiculate with defined raised midrib, the apiculum *c*. 0.5 mm long, the abaxial surface densely sericeous, the hairs ferruginous with some scattered white hairs. *Flowers* zygomorphic, adaxially oriented, dichromatic *in vivo*, green in bud, the abaxial surface of the perianth cream at anthesis, the adaxial surface white; style pink at base green to greenish white elsewhere prior to anthesis, whitish-cream after anthesis, entomophilous, scent not recorded; *pedicels* 3–4 mm long, 0.25 mm wide at mid-point, 0.3 mm wide distally, terete but abruptly expanded below the torus with pronounced dorsal attenuation, a dense to sparse indumentum of biramous, appressed, white hairs *c*. 0.3 mm long proximally, the hairs becoming sparse distally, scattered erect glandular hairs sometimes intermixed; *torus* oblique at *c*. 45°–60°, 1.5 mm across, irregularly oblong-elliptic, truncate ventrally, attenuate dorsally, cupuliform; *nectary* long V- to U-shaped, lining the inner surface of the torus, only the margin extending above and over the toral rim, 0.1–0.2 mm thick, erect; *pistils* 16–17 mm long, glabrous; *gynophore* 2.5–3 mm long, 0.2–0.3 mm wide, angularly inserted, adnate to the dorsal surface of the invaginated torus for *c*. 0.5 mm, refracted ± orthogonally just below the toral rim (realigned roughly parallel to the pedicel); *ovary* 0.7 mm long, 1.0 mm wide, oblong-elliptic to subglobose, lateral, conspicuous, the base truncate to ascending, not retrorse; *style* 0.3 mm diameter, cream in the proximal half, greenish distally, smooth, exserted before anthesis, hooked subapically; *style-end c*. 0.3 mm wide, terminated in the distal half on the back of the pollen-presenter; *pollen-presenter* 1.8 mm long, 1.0–1.2 mm wide, *c*. 0.1 mm thick, green, lateral to very oblique at *c*. 80°, oblong to oblong-elliptic with rounded corners, the surface flat, the margin undulate, thin; stigma slightly raised, central to distally off-centre; *perianth* 4.5–5.0 mm long, 1.25 mm wide, the tube oblong-triangular without basal dilation, persistent, the abaxial surface openly sericeous in young bud, the hairs mostly evanescent, scattered appressed hairs retained near the base and on the limb at anthesis, the adaxial surface glabrous at base, densely papillose and loosely pilose from *c*. 2.0 mm above the torus to the curve, the indumentum situated mostly adjacent to and above the level of the ovary but not condensed into a dense beard, the papillae minute, the trichomes (0.2–)0.7–1.0 mm long, unbranched, robust, straight to slightly flexuous with acute tip; perianth limb *c*. 2.0 mm across, depressed-globose to cushion-like, dorsiventrally compressed, tightly revolute in the distal quarter, with scattered appressed biramous hairs and usually with numerous short erect glandular hairs intermixed, concolorous *in sicco*; *dorsal tepals* 9.5–12 mm long, 0.5–0.8 mm wide, narrow-ovoid; *ventral tepals c*. 6.5 mm long 1.25 mm wide at base, ovoid; *tepals* each with a prominently raised longitudinal mid-rib below the limb on the abaxial surface, grooved on the adaxial surface, the rib forming the axis of angular tepal infraction, attached at base directly to the outer margin of the toral rim, ontogenetically first separating along the dorsal suture, everting and all tepals separating from each other to base before anthesis, the adaxial surface conspicuously exposed; *tepal-limbs* remaining strongly coherent, ultimately all free and loose at anthesis, not recoiled. *Fruits* 10–12 mm long, 8–10 mm wide, 7 mm thick, erect to antrorsely oblique with attachment posterior-basal, the ventral suture adaxially oriented, dispermous, usually persistent, tightly enclosing the seed body, obovoid-globose, green when young ageing black, soon greyish black, the *follicle valves* thick-walled, remaining coherent after dehiscence along the dorsal suture and at base, very slightly compressed, detaching when ripe with pedicel attached; axial tissue of the gynoecium above the gynophore and below the fruiting style concurrent; fruiting style obliquely subterminal on the dorsal side of pericarp, fragile; *pericarp* 1.75– 2 mm thick at the suture, 0.6–1.0 mm thick at centre-face, 1.4–1.6 mm thick at the dorsal side; *exocarp* *c*. 0.1 mm thick at the suture, discolorous, smooth to colliculose or obscurely verrucose or rugulose, shiny, tessellated with age, not transversely ridged, non-viscid; *mesocarp* 1.25–1.5 mm thick at the suture, with a hard outer zone *c*. 1 mm thick, consisting of white, stone-like intrusions and a softer inner surface *c*. 0.5 mm wide, discolorous with pebble-like texture; *surface of the suture* grooved and with papyraceous deposits on the ventral suture; *endocarp c*. 0.2 mm thick, black, rugose, ultimately flaky, differing markedly in texture from the mesocarp, broadly concave and roughly coursing the outline of the exocarp; *texture* bony. *Seeds* (*ADC 2353*) 9 mm long, 4 mm wide, peripterous; *seed body* 8 mm long, 2.7 mm wide, 1 mm thick, obovate, acute and slightly compressed at the micropyle end, obtuse at the chalaza end; *abaxial surface* convex, without secondary development, smooth, mottled with scaly particles, *adaxial surface* 7 mm long, 1.8 mm wide, linear, very slightly convex, flat for 0.8mm at the triangular apex, with a smooth, raised membranaceous rim *c*. 0.25 mm wide around the margin, surface smooth; *seed wing* 0.5–1.2 mm wide, fragile, membranaceous; *elaiosome* absent; *raphe* sub-basal, conspicuous; *hilum* obscure. (Figs 1–3)

Fig. 1. *Grevillea tesselata* Olde (drawn from *Hislop 3743*). **a**. Habit with fruit. **b**. Style-end close-up. **c**. Flower post anthesis. **d**. Conflorescence bud. **e.** Flower before anthesis. **f**. Perianth limb close-up. **g.** Nectary and stipe lining the torus. **h**. Flower section showing zygomorphic torus, ovary orientation. **i**. Fruit: ventral view showing basal attachment. **j, k**. Seed (above and below). **l.** Fruit: side view with tesselated exocarp and concurrent gynoecial tissue × 4. **m.** Fruit: internal side view × 4. Scale bar: **a** = 40 mm; **b, d, g, h** = 4 mm; **c, e** = 6 mm; **f** = 2 mm; **i–m** = 15 mm. Illustration by Lesley Elkan.

Fig. 2. *Grevillea tesselata*. A. Conflorescence. B. Plant habit with serotinous fruits. Photos: A by Phil Lewis; B by Peter Olde.

Fig. 3. Fruit capsules and seeds. A. *Grevillea tesselata*. B. *Grevillea acacioides*. C. *Grevillea endlicheriana*. Photos: A, B. by Peter Olde; C by Mark Noake.

Diagnostic characters: Similar to *Grevillea acacioides* due to the regular dome-shaped conflorescences and adaxially oriented flowers, but differing in its leaves with a single rib, usually longer, occasionally divided, its conflorescences 20–30-flowered, acropetal, its peduncles longer (8–10 mm long), ferruginous, its rachises longer (8–12 mm long), sericeous, its common bracts glabrous-ciliate, not imbricate, its torus dorsally attenuate, cupuliform, its nectary obscure, its pedicels shorter (3–4 mm long) and sparsely sericeous, its perianth sparsely sericeous on the outside, pilose inside, the hairs longer, not condensed into a beard, the limb minutely glandular, the limb segments not ribbed, its pistils longer (*c.* 16 mm long), its gynophore longer, its carpel not retrorse, its pollen-presenter sublateral, wider and longer and un-rimmed; its fruits ellipsoidal, connected at the base and coherent after anthesis, the exocarp tessellated, not transversely costate, the mesocarp not spongy, the obovate seeds convex on the adaxial surface, not partially enclosed by a revolute margin.

Distribution: Western Australia, South-west Botanical Province, in the Katanning, Merredin Subregion of the Avon Wheatbelt IBRA Region ABRA 5.1, Trayning Shire.

Habitat and ecology: Occurs in slight depressions of an otherwise flat plain in open acacia-eucalypt woodland with *Melaleuca uncinata,* and chenopods in pale, sandy saline clay-loam with some laterite. Associated species recorded on specimen labels include *Acacia* sp., *Cassytha* sp., *Daviesia nematophylla*, *Enchylaena tomentosa*, *Eremophila drummondii*, *E. oppositifolia*, *Eucalyptus salmonophloia*, *Grevillea acuaria*, *G. hakeoides* subsp. *stenophylla*, *G. hookeriana*, *G. huegelii*, *G. paniculata*, *Hakea recurva*, *Maireana* sp., *Melaleuca acuminata*, *M.* ?*lanceolata, M. pauperiflora* subsp. *fastigiata, Olearia* sp. and *Santalum* sp.

Selected specimens seen (10 examined): WESTERN AUSTRALIA: [precise locality withheld, all from the same location], W. of Trayning, *A. Crawford ADC 2353,* undated [2013] (NSW, PERTH); *M. Hislop 3744*, 15 Dec 2007 (PERTH 07695659, NSW 536133); *W. Johnston WJ 071*, Dec 2006 (PERTH); *N. Marriott 1023*, 17 Sep 2010 (MEL, NSW871898); *P.M. Olde 13/400 & F. & J. Hort*, 9 Sep 2013 (NSW, PERTH, distribuendi).

Phenology: Flowers in late spring–summer with fruits forming from mid-January.

Conservation status: Currently listed as Priority One under Western Australian Conservation Codes (Western Australian Herbarium 1998–). This species should be considered for listing as Critically Endangered due to its extremely limited distribution and number of individuals. *Grevillea tesselata* was discovered in December 2006 and is confined to a single population fragmented within a relatively short length of disturbed road verge. A few plants have regenerated beside the disused, rail-line running parallel to the road. The population consists of less than 50 individual plants and is clearly threatened at the species level.

Etymology: From the Latin *tesselatus* (tessellated), a reference to the crazed exocarp of this species that is visible soon after fruit dehiscence.

Notes: *Grevillea gordoniana* differs from *G. tesselata* by its sub-arborescent habit, its longer, non-grooved, terete leaves 15–36 cm long, in its emergent, multi-branched conflorescences, imbricate in bud and developing basipetally, its inflorescence rachises, perianth and pedicels glabrous, its gynophore longer (2.3–2.6 mm long), its fruits longer (23–28 mm long) and sigmoid-ellipsoid to obovoid in shape, the exocarp viscid, rugose, ultimately with resinous deposits, its seeds linear with wing attenuated at each end.

Grevillea acacioides differs in its leaves always simple, crowded, usually shorter, mostly straight, subterete, multi-ribbed *c.* 0.8 mm wide diam. (up to 1.75 mm wide in some specimens with leaves elliptic in cross-section); its conflorescences 8–16-flowered, conspicuously imbricate with basipetal development; its peduncles white-sericeous to white-tomentose; its inflorescence rachises tomentose to villous, often with glandular hairs intermixed; its common bracts absent; its involucral bracts 2–5 mm wide; its pedicels longer (4–7.5 mm long), and glabrous; its perianth glabrous on the abaxial surface, the hairs on the adaxial surface curled or sinuous

and condensed into a beard, the tepal-limbs with a prominent mid-rib; its torus oblique at *c.* 30°, but narrower (0.8–1.1 mm across), subregular, not dorsally attenuated, not cupuliform; its nectary prominent, semi-annular to broadly U- or V-shaped, lobed at each end; its pistils shorter (10–12.5 mm long); its ovary retrorse; its gynophore 1–1.3 mm long, vertically inserted, not lining the inside of the torus and infracted at its rim, its pollen-presenter smaller, oblique at *c.* 30°, oblong to round, conical, 0.7–1.2 mm long, 0.6–1.0 mm wide, 0.2–0.4 mm high, surrounded by a thin collar of style-end tissue and attached to the style-end on its dorsal side in the proximal half; its fruits sub-ellipsoidal with a shallow embayment on the dorsal side, deciduous, the valves dis-coherent after dehiscence and falling separately, the gynophore lateral, excurrent, detached from the pedicel before falling, the abaxial surface dull, brown or creamy, rugose with smooth undulations and with a raised, transverse band across the abaxial surface of each valve in the proximal half, the mesocarp thick, spongy; its seeds smaller, linear to narrow-elliptic, the adaxial surface deeply channelled with conspicuous raphe and hilum, on the abaxial surface abruptly convex beyond a low-profile elliptic terminus 0.8 mm long.

Grevillea endlicheriana differs in its lignotuberous habit, its polymorphic leaves always simple, terete or sometimes dorsiventral with tri-ribbed abaxial surface, its emergent, multi-branched conflorescences, the development of the whole conflorescence and each unit conflorescence basipetal, its peduncles secondarily branched, often angular, white-sericeous, its pedicels glabrous, its torus transverse to slightly oblique, not dorsally attenuate, its perianth glabrous on the abaxial surface, its fruits red when young, transversely attached to the dorsal suture but otherwise similar in shape to those of *G. acacioides*.

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A new synonym of the endangered species *Paphiopedilum papuanum* (Orchidaceae)

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Abstract

Paphiopedilum sandyanum Cavestro and G.Benk is a newly published species from Moluccas, Indonesia. After meticulous examination and morphological comparisons, it has been concluded that *P. sandyanum* is conspecific with *P. papuanum* (Ridl.) L.O.Williams. Comparison of morphological characters between these two species is provided below. Moreover, information is provided on newly discovered *P. papuanum* populations from near the type locality of *P. sandyanum*.

Keywords: *Paphiopedilum sandyanum*, *P. papuanum*, endangered species, Papua, synonym.

Introduction

Paphiopedilum papuanum (Ridl.) L.O.Williams was established based on *Cypripedium papuanum* Ridl. (Williams 1946). The species had first been collected by C. B. Kloss on the British Wollaston expedition in Mount Carstensz, New Guinea (Rendle 1915). This species is closely related to *Paphiopedilum violascens* Schltr., which Schlechter had described only four years earlier and came from the eastern part of New Guinea (Schlechter 1911). *Paphiopedilum papuanum* is characterized by thick, leathery, tessellated leaves, a one-flowered inflorescence, oblong and obtuse petals with blackish dots at the base, and a lunate-reniform staminode (Ridley 1915). *Paphiopedilum papuanum* is currently placed in *Paphiopedilum* section *Barbata* (Kraenzl.) V.A.Albert & Börge Pett. (Albert and Pettersen 1994).

Recently, *Paphiopedilum sandyanum* Cavestro and G.Benk was published as a new species of *Paphiopedilum* section *Barbata* from Maluku Tenggara Regency, Moluccas, Indonesia (Cavestro and Benk 2022). Those authors first compared their Moluccas material with *P. mastersianum* (Rchb.f.) Stein and *P. schoseri* Braem & H.Mohr occurring on the Moluccas and then with *P. violascens* from New Guinea. However, they did not compare *P. sandyanum* with *P. papuanum* which has more similarities. We could not check the type specimen because it is not yet deposited in the Herbarium Bogoriense. We also confirmed with the collector of *P. sandyanum*, Sandy Jacop, that the type specimen has not yet been deposited and is still being processed and prepared for submission.

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Upon examination of the morphological descriptions in the protologues of both *P. sandyanum* and *P. papuanum*, we found that both species have ovate, hairy bracts, an ovate dorsal sepal, oblong and slightly spatulate petals with blackish dots at the base, and a lunate to reniform staminode (Table 1). We found no significant deviation from the typical form of *P. papuanum* that would possibly justify formal classification as a geographically-based variety or forma. In addition, one of us (RS) discovered *P. papuanum* in Fakfak Regency (Fig. 1), which is adjacent to the *P. sandyanum* locality in Maluku Tenggara Regency. Based on the above data, we consider *P. sandyanum* and *P. papuanum* to be conspecific.

Taxonomic treatment

Paphiopedilum papuanum (Ridl.) L.O.Williams, *Bot. Mus. Leafl.* 12: 149 (1946). *Cypripedium papuanum* Ridl. in A.B.Rendle, *Gard. Chron.* ser. 3, 58: 131 (1915). *Type*: Indonesia, Papua Province, Irian Jaya, Mt. Carstenz, elev. 762 m, [Dec. 1914–Jan. 1915], *C.B. Kloss s.n.* (holotype: BM!).

Paphiopedilum sandyanum Cavestro and G.Benk, *Die Orchidee* 8(7): 46 (2022), **syn. nov**. *Type*: INDONESIA: Moluccas: Maluku Province, Kabupaten Maluku Tenggara, 300–400 m asl, 15 March 2022, *S. Jacop* (holotype: cited as BO, but not yet deposited).

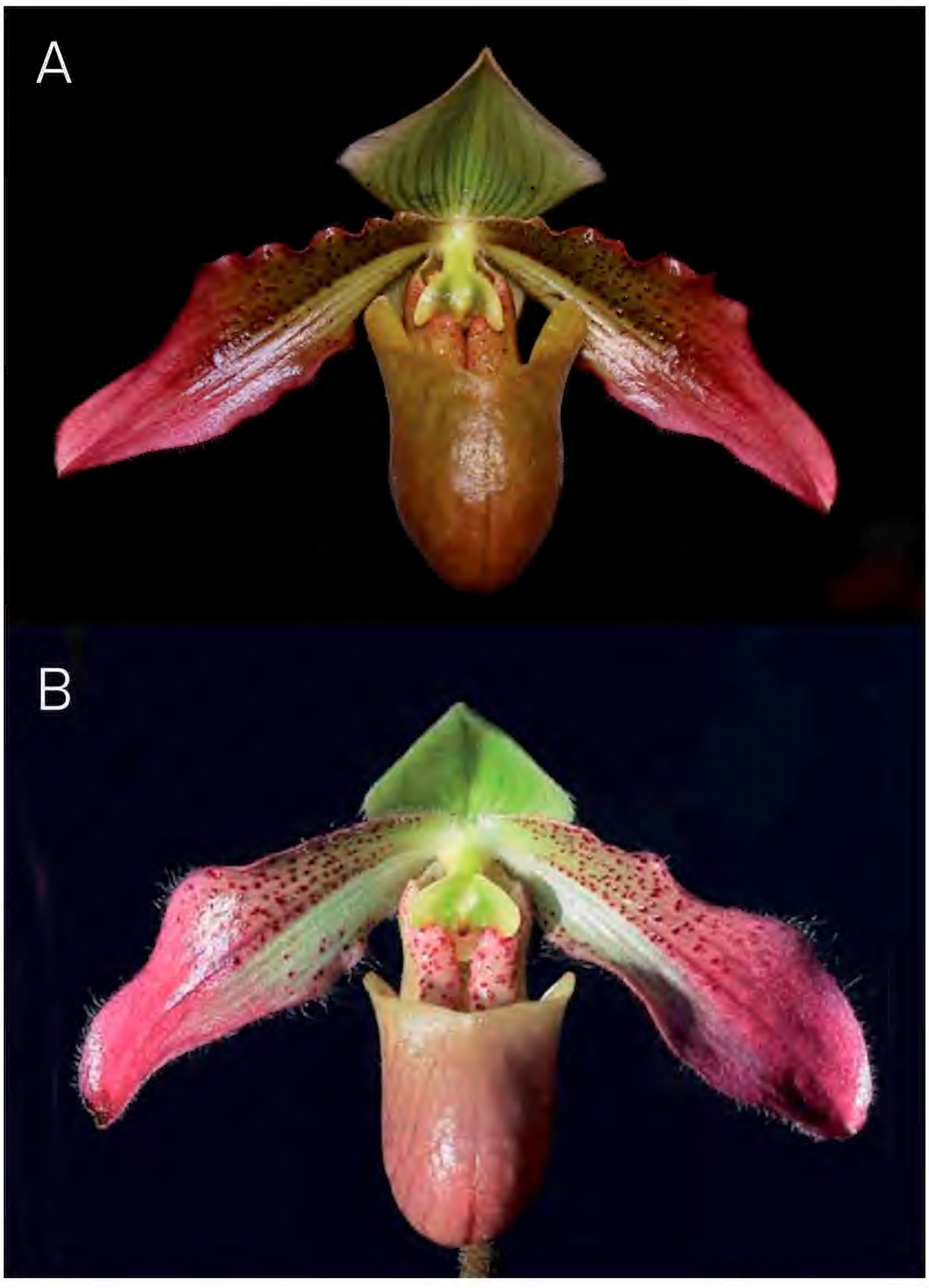

Fig. 1. Front view of (A) *Paphiopedilum papuanum* from Fakfak Regency and (B) *Paphiopedilum sandyanum* from Moluccas. Photos by Reza Saputra (A) and Gus Benk (B).

Table 1. Comparison of morphological characters between *P. papuanum* based on Ridley (1915: 131) and *P. sandyanum* based on Cavestro and G.Benk (2022: 45–46) and a drawing by Sandy Jacop.

Character	*P. papuanum*	*P. sandyanum*
Leaf colour	pale green with darker green markings on the ripper face	green and mottled pale green on upper surface
Bract	ovate, pubescent, 1.3 cm long	elliptic-ovate, pubescent, 1.5 cm long
Dorsal sepal	ovate, acute, 2.4 × 2 cm	ovate, obtuse, 2.8–3 × 2 cm
Lateral sepals	elliptic-lanceolate, subacute, 1.9 × 0.8 cm	cordiform, obtuse, 2 × 1.8 cm (1.95 × 1.65 cm in drawing)
Petals	oblong, broadening slightly upwards, obtuse 4.2 × 1.2 cm, dull crimson dotted with darker spots in the lower half	obliquely oblong, slightly spatulate, obtuse, 4–4.6 × 1.5 cm (4.6 × 1.43 cm in drawing), brown spotted in lower basal half
Labellum	3.7 cm long	c. 4 cm long (4.1 cm in drawing)
Staminode	lunate to reniform	lunate to reniform

Specimen examined: INDONESIA: New Guinea: Papua Barat Province, Fakfak Regency, Fakfak Mountains, 792 m asl, 22 January 2022, *Reza 412* (MAN!, BO!).

Conservation status: Currently, *P. papuanum* is categorized in The IUCN Red List of Threatened Species as an Endangered species, due to the threat of illegal export for regional and international trade for horticultural purposes and hybridization (Rankou 2015). To prevent illegal export, based on Indonesian Regulation (Keputusan Menteri Kehutanan No. 447/Kpts-II/2003), all wild plants species require a transport permit called *Surat Angkut Tumbuhan Dalam Negeri* (SATDN) for regional shipping.

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A new species of *Calandrinia* (Montiaceae) from rocky pavements in eastern New South Wales and south-eastern Queensland

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Abstract

Calandrinia petrophila J.G.West & Albr. *sp. nov.* is described and illustrated, with notes on distribution, habitat, conservation status and features distinguishing it from similar species of *Calandrinia*.

Introduction

Since the mid-2000s more than 20 new Western Australian species of *Calandrinia* have been described, elevating the number of currently recognised named Australian *Calandrinia* species to 61 (Western Australian Herbarium 1998–; Northern Territory Herbarium 2015–; VicFlora 2016–; de Salas & Baker 2019; Thomas & Brown 2020; Flora SA 2021; PlantNET 2021). Collectively these references recognise a further 25 undescribed species with phrase names. New species have continued to be named in *Calandrinia* despite significant evidence (Carolin 1987; Hershkovitz 1998; Nyffeler & Eggli 2010; Thiele et al. 2018; Hancock et al. 2018) that Australian members of the genus are genetically distinct from those species in the Americas. Two alternative generic names, *Rumicastrum* Ulbr. (described in 1934) and *Parakeelya* Hershk. (described in 1999) have been proposed for the Australian species of *Calandrinia*, though neither has been adopted to date. Reasons in favour of adopting *Rumicastrum* were presented by Hershkovitz (2020), whilst those in favour of adopting *Parakeelya* were presented by Thiele et al. (2018). A proposal to conserve the name *Parakeelya* against *Rumicastrum* is awaiting consideration by the Nomenclature Committee for Vascular Plants (Thiele et al. 2018).

In this paper we describe a new species from eastern New South Wales and south-eastern Queensland that has been recognised as distinct for many years. It is named as a species of *Calandrinia* noting that the generic name will need to be changed in the future once the outcome of the proposal to conserve *Parakeelya* is voted on at the International Botanical Congress scheduled for 2024.

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Methods

Measurements presented in the species description are based predominantly on rehydrated dried specimens and field collected live plants, with additional measurements from live cultivated material grown under favourable conditions at the Australian National Botanic Gardens (ANBG).

The flower–bearing shoots were measured in two parts. The proximal leafless portion was measured from the base to the insertion point of closest bract above (i.e. where the first pedicel of the inflorescence arises). The distal flowering portion (i.e. inflorescence axis sensu Obbens 2011) was measured as the distance from the lowermost bract to the apex of the distal-most bud or flower. Pedicel length was measured as the distance from its apex (at the junction with the sepals) to the insertion point of the closest bract below. For the purposes of consistency with descriptions of recently described species we here treat the two structures below the petals as sepals although it is acknowledged that they are considered to correspond to bracteoles or involucral bracts by some authors (see Nyffeler and Eggli 2010 for discussion). These structures were detached and flattened to measure. Fruit measurements are based on unflattened mature fruits prior to dehiscence.

Taxonomy

Calandrinia petrophila J.G.West & Albr., ***sp. nov.***

Type: New South Wales: Southern Tablelands: 16 km from Nerriga along road towards Nowra, c. 6km NW of Sassafras, 19 Feb. 1982, *I.R.Telford 8677* (holo: CBG 8200581; iso: NSW, BRI).

Calandrinia sp. Nerriga (I.R.H.Telford 8677) NSW Herbarium

Calandrinia sp. A sensu Fl. NSW 1: 183 (1990)

Glabrous perennial herb to c. 5 cm high with branching tuberous roots; finer roots arising from tuberous roots. *Leaves* all basal, mostly spreading, sometimes flat on substrate surface, succulent, dull green, paler at very base, progressively becoming suffused with yellow or orange with age or desiccation, linear, linear–oblanceolate or linear–elliptic, 20–60 mm long (–120 mm in cultivation), 1.0–3.0 mm wide (–5.8 mm in cultivation), dorsi-ventrally compressed, 1.0–2.5 mm thick, flat to slightly convex adaxially with or without a slightly depressed medial longitudinal area, flat to slightly convex abaxially or broader leaves with a slightly raised broad midrib and sometimes also with a slightly raised broad marginal rim; base attenuate; margins rounded in x-section for most of leaf length but becoming more angular proximally; apex narrowly rounded to acute. *Flower-bearing shoots* arising from leaf axils, sometimes prostrate on substrate surface, not or rarely slightly exceeding the length of the longest leaves; proximal leafless portion 8–30 mm long; distal flowering portion 15–65 mm long, flowers arranged in (1–)2–5(–7)-flowered monochasial cymes or dichasial cymes with monochasial branches, pedicels 1.5–7 mm long, distinctly broader distally, not obviously elongating in fruit; bracts opposite at each node, appressed or ascending, triangular, deeply concave, the bract adjacent to the pedicel often the smaller of the pair, 0.5–4.5 mm long (–7 mm in cultivation), the bract adjacent to the inflorescence axis 1.7–5 mm long (–12 mm in cultivation), herbaceous with hyaline margins becoming broader towards the base, acute. *Flowers* 6–12 mm diameter. *Sepals* ovate to broadly ovate, (3.0–)3.5–5.0(–6) mm long, 2–4.2 mm wide, persistent, free to base, venation not evident; margins narrow, hyaline, to c. 0.3 mm wide; apex broadly acute to obtuse. *Petals* 4–5, white, broadly lanceolate to ovate or elliptic, (2.2–)3–6.5 mm long, 1.2–3 mm wide, free or virtually so, apex broadly acute to obtuse. *Stamens* 4–5(–6); filaments white, linear, appearing free but attached to the top of a basal ring subtending ovary, 2–3 mm long, smooth; anthers cream, versatile, 2-celled, each cell oblong in outline, 0.2–0.7 mm long, 0.15–0.25 mm wide, latrorse, dehiscing longitudinally. *Ovary* pale green, ovoid, 1.5–3 mm long, 0.7–2.2 mm diameter. *Stigmata* 4, white, linear, 0.5–1 mm long, free to the base. *Capsule* ovoid to conical-ovoid, 4.0–5.2 mm long, 1.8–2.3 mm wide, exceeding the sepals, apex truncate; valves 4, persistent, firm-textured, when dry the external surface with numerous slightly raised short longitudinal lines, not splitting more than halfway to the base. *Seeds* numerous, obovoid, mid to dark brown, unevenly shiny due to surface pattern, (0.4–)0.45–0.6 mm long, 0.35–0.5 mm wide, colliculate, with a rudimentary strophiole. (Fig. 1).

Diagnostic characters: A distinctive species distinguished from other *Calandrinia* spp. by the combination of the following characters: leaves strictly basal, narrow and dorsi-ventrally compressed; flower–bearing shoots not or rarely slightly exceeding the length of the longest leaves; bracts opposite; petals white, 4 or 5; stamens 4–6; stigmas 4; capsules with 4 persistent, firm-textured and truncate valves with a distinctive surface pattern; and seeds colliculate.

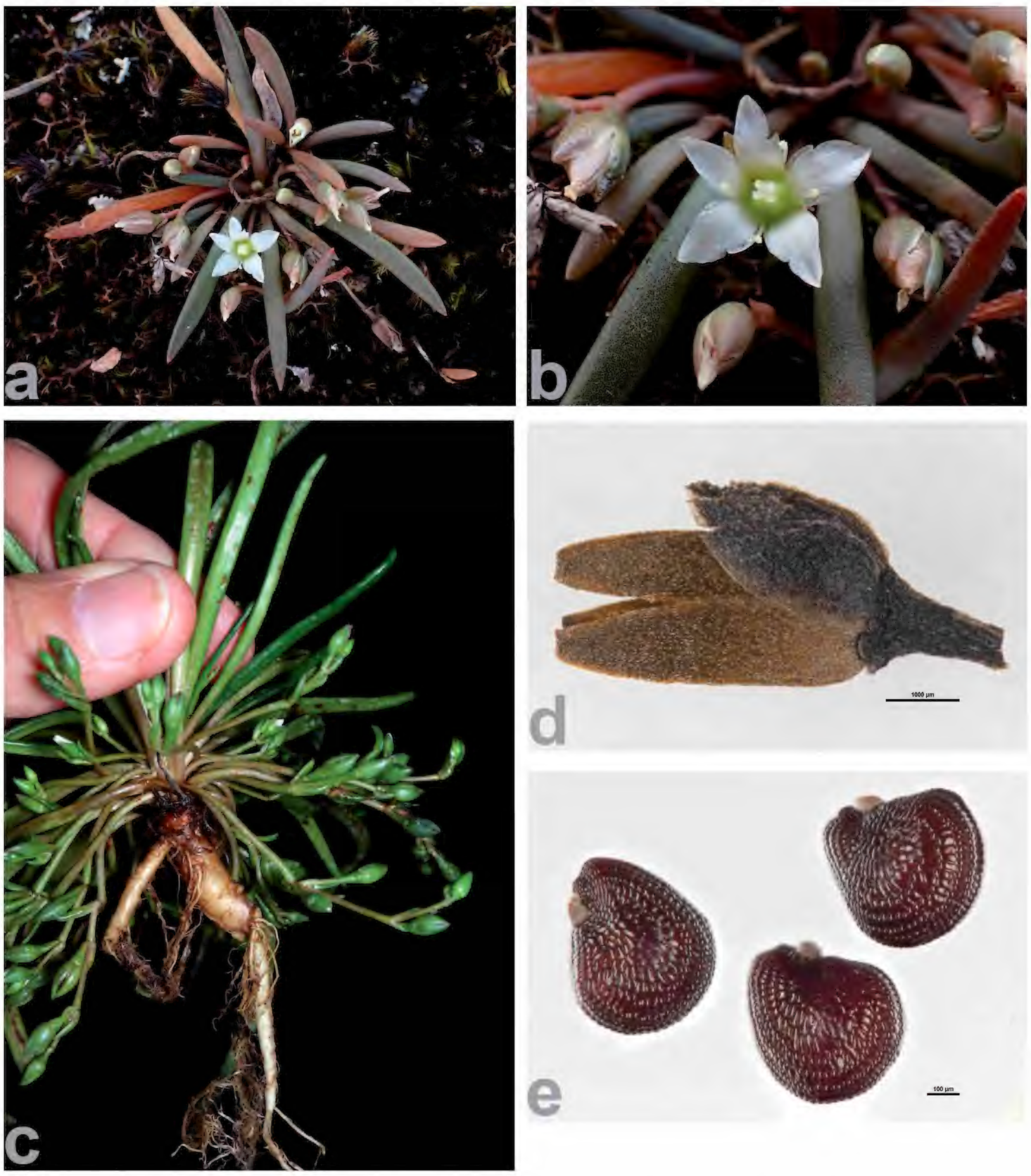

Fig. 1. *Calandrinia petrophila*: **a.** habit; **b.** flower; **c.** whole plant showing root system; **d.** dehiscing capsule showing external surface texture, one subtending sepal removed; **e.** seeds. Scale bars: a & c = 10 mm; b = 2.5 mm. Images a & b = T.Collins (*Albrecht 16362*); c = M.Fagg (cultivated ex *Albrecht 16362*); d = J.FitzGerald (*West 4642*); e = J.FitzGerald (*West 5554*).

Specimens examined: QUEENSLAND: Darling Downs: Burncluith Road to Barakula State Forest, Jan 1980, *M.G.Lithgow 672* (BRI); Chinchilla area, Oct 1978, *M.G.Lithgow s.n.* (BRI); Rosedale, c. 18km south west of Chinchilla, 9 Dec 2010, *C.Eddie CPE1740* & *R. Aisthorpe* (BRI); 9km E of Condamine, 2 Dec 2013, *C.Todd s.n. & S.Leicaster* (BRI); Headwaters of Pariagara Creek, 7km W of Bringalily Forestry Lookout Fire Tower (abandoned), 26 Sept 1982, *P.I.Forster 11653* & *P.Machin* (BRI); Three Mile Station, Stanthorpe, 15 April 1961, *W.G.Trapnell 10* (BRI).

NEW SOUTH WALES: North Coast: On a property known as "Archerfield" in the Mount Thorley - Warkworth area, c. 8 km N of the Golden Hwy and 1 km W of the Hunter River, 18 Oct 2011, *A.N. Rodd s.n.* (NSW). Central Tablelands: cultivated Fairfield [NSW] ex The Grandstand [The Lookout], Bindook Highlands, Blue Mountains National Park, 5 Nov 2005, *C.P.Gibson, R.T.Miller & G.W.Carr s.n.* (NSW). Southern Tablelands: c. 6.3 km due N of the intersection of Tolwong Road and Braidwood Rd (c. 11 km due NE of Nerriga), 18 Apr 2021, *D.E.Albrecht 16362 & T.Collins* (CANB); Near Bulee Gap, 5.5 km NE of Nerriga, 26 Nov 1981, *I.R.Telford 8668 & J.W.Wrigley* (CBG); Morton National Park, on Braidwood-Nowra Rd, 5.5 km NE of Nerriga, 5 Dec 1981, *J.G.West 4642* (CANB); 1.6 km east of Sassafras on road to Tomerong, 1 Nov 1984, *J.G.West 4952* (CANB); Middle Creek, 3.2 km S of Sassafras, 24 Mar 1974, *I.Olsen 1988* (NSW); 1 km S of Round Hill, Northern Budawang Range, 31 Jan 1977, *J.Pickard 3321* (NSW); 7.5km S of Sassafras, 8 Mar 1975, *J.G.Seur 198 & S.Jacobs* (NSW); Northern Budawang Range, Folly Point track, 3 km S of Newhaven Gap, 4 May 1991, *I.R.Telford 11003 & R.Rudd* (CBG, NSW). South Coast: Tullyangella Labyrinth, 7 km N of Bulee Hill, 27 Jan 1984, *I.R.Telford 9642* (CBG, NSW, BRI); E of Sassafras along Turpentine Road, (c. 200 m S of road), 6.5 km (direct) NE of Tianjara Falls, 8.3 km W (by road) of Tomerong turnoff, 16 Nov 2011, *J.G.West 5554* (CANB); Morton NP, NW of Milton, along Mt Bushwalker walking track, Little Forest Plateau, 9 Dec 2020, *J. Miles 21-09* (CANB).

Distribution: Based on specimens in Australian herbaria *Calandrinia petrophila* is currently known from four disjunct regions (Fig. 2). Most collections have been made from the southern part of its range in the Budawang Range of south–eastern New South Wales, with several collections made in the Queensland Darling Downs at the northern edge of its range. Only two collections have been made between the northern and southern clusters – one from the Bindook Highlands in the southern part of the Blue Mountains National Park and another from north-west of Singleton. It is probable that the species is under collected as several unvouchered records of it are on iNaturalist (currently as *C. eremaea* Ewart or *C.* sp.), including one from just north of Torrington, New South Wales, c. 75 km from an existing vouchered collection site (iNaturalist 2020).

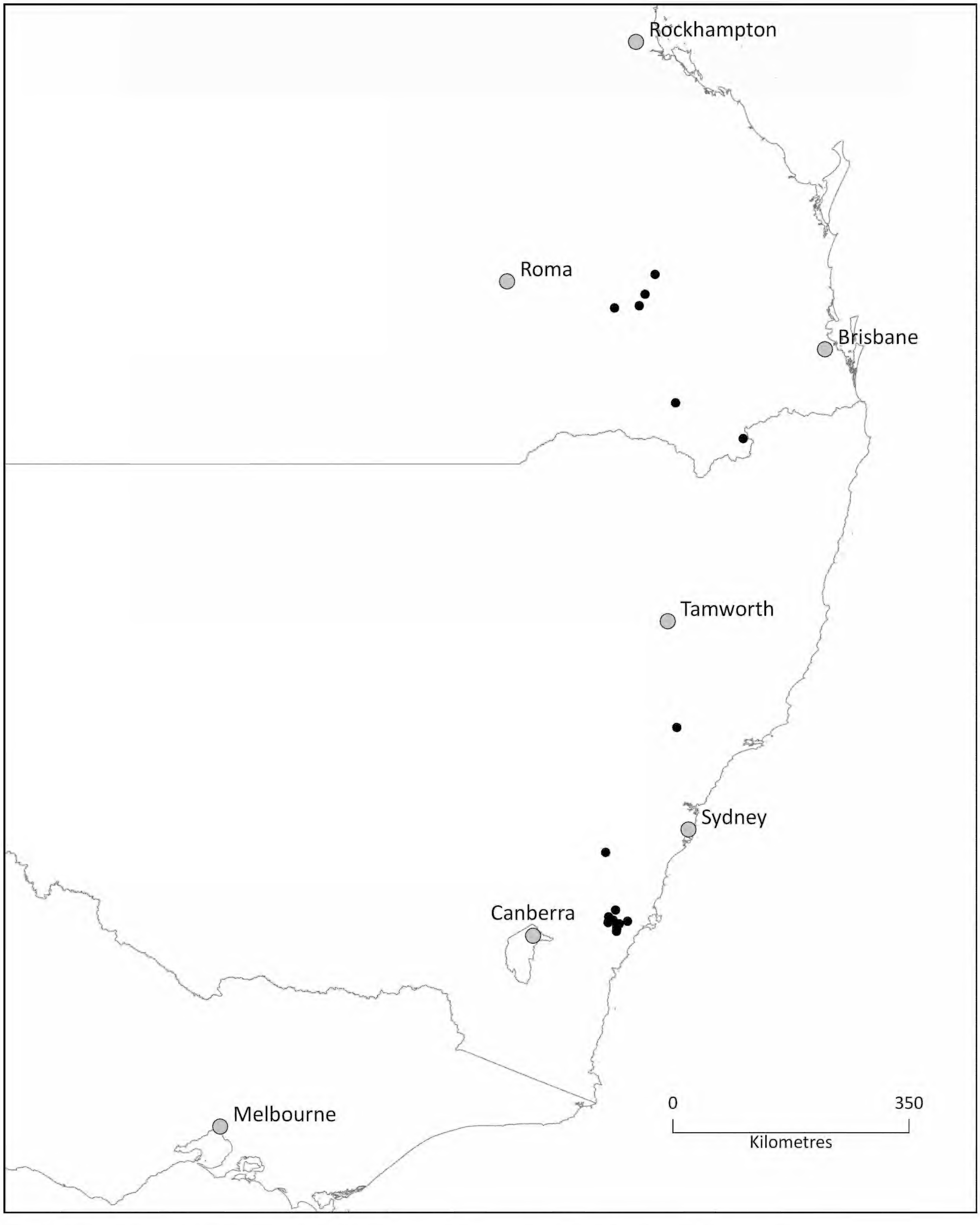

Fig. 2. Distribution of *Calandrinia petrophila* based on specimens lodged at CANB, NSW and BRI.

Conservation status: Although the species has been recorded from at least twenty sites little is known about the size of populations. Until further field assessments are undertaken a conservation code of *data deficient* would seem appropriate. Although plants were present at two sites in the Budawangs visited after the 2020 bushfires, the impact of these fires on populations is uncertain as no pre-fire population size data is available for comparison. Given that the species typically occurs on exposed sites with shallow soils over rock, drought may be a key risk. The southern populations occur within Morton National Park and the population from the Bindook Highlands occurs within the Blue Mountains National Park.

Habitat: Throughout its geographic range *Calandrinia petrophila* occurs principally on flat to gently sloping rock pavements in low open vegetation. Plants are frequently found growing in cryptogam mats on shallow soil over sandstone, or less frequently granite or conglomerate bedrock (Fig. 3). On sandstone sites in the southern part of its geographic range associated species include *Rytidosperma monticola*, *Centrolepis strigosa*, *Schoenus ericetorum*, *Lepidosperma viscidum*, *Crassula sieberiana*, *Platysace lanceolata*, *Goodenia bellidifolia* ssp. *bellidifolia* and seedlings of various shrub species from the surrounding heathland, shrubland or heathy forest/woodland vegetation. *Calandrinia eremaea* and *C. pickeringii* co-occur at some sites. Habitat notes on two collections from Queensland and one from the Hunter region in NSW suggest that the species also rarely occurs on non-rocky sites, though in some cases the information provided is not detailed enough to be certain. These apparently atypical habitats include grassland dominated by *Aristida caput-medusae* and *Eragrostis* sp. on a plain in brown clay loam (C.Eddie CPE1740 & R.Aisthorpe); cleared grassland, grazing land, shallow brown duplex soil (C.Todd s.n. & S.Leicaster); and open areas in a stand of *Eucalyptus crebra* with *Melaleuca thymifolia*, *Murdannia graminea*, *Laxmannia gracilis*, *Cheilanthes sieberi* and *Aristida ramosa*, with some exotic species (A.N.Rodd s.n.). The latter site supports an unusual floristic assemblage that may align with the critically endangered Warkworth Sands woodland of the Hunter Valley (Department of the Environment 2021). This site also supports an unusual disjunct population of *Calandrinia balonensis* (Tony Rodd pers. comm.).

Fig. 3. Typical habitat of *Calandrinia petrophila* = M.Fagg (*West 5554*) ©M. Fagg, 2011.

Phenology: Flowering specimens have been collected in the field between September and April, and fruiting specimens between October and May. Adequate soil moisture, light and sufficiently high ambient temperatures appear to be important for flowers to develop and open.

Etymology: The specific epithet is derived from the Ancient Greek *pétros* meaning "rock" and *phíleo* meaning "to love" in reference to the rocky habitat where most records of the species have been made.

Affinities: On occasions, *Calandrinia petrophila* has been confused with *C. pickeringii* and *C. pleiopetala*, but the relationship between these species and *C. petrophila* is probably not particularly close. *Calandrinia pickeringii* is readily separated from *C. petrophila* by having cauline leaves on at least the lower stems, smaller sepals (2.5–3(–3.5) mm long), pink petals, smaller capsules (2.5–4 mm long) with a subacute to somewhat nipple-like apex and 3 non-persistent thinner-textured valves that separate from base upward, and larger seeds (0.6–0.8 mm long) with a papillate-punctate surface pattern. *Calandrinia pleiopetala* differs most noticeably from *C. petrophila* in having 8–10 larger pink petals, and numerous (>20) stamens.

Dried herbarium specimens of *Calandrinia petrophila* are superficially similar to an undescribed species from northern Australian estuaries known variously as *C.* sp. Berry Springs (M.O.Parker 855) or *C.* sp. Olive River (J.R.Clarkson 10012). However, that species differs from *C. petrophila* in a range of features including having alternate bracts, fruiting pedicels 4–23 mm long, non-persistent sepals, 6–7(–8) pale pink or rarely white petals to 3.5(–4) mm long, smaller (2–3.2 mm long) obtuse to subacute capsules that split into 5–7 non-persistent valves, and smaller paler brown seeds mostly 0.35 mm long and 0.25 mm wide, that are more evenly shiny and very faintly patterned. *Calandrinia pumila* also has a similar habit to *C. petrophila* and has opposite bracts, however *C. pumila* has spathulate to narrowly obovate leaves, smaller sepals (1.5–3 mm long), generally smaller (1.8–4 mm long) pink or rarely white petals, 3 stigmata, smaller (2–3.5 mm long) thinner-textured basally circumscissile broadly ovoid to globose fruits that lack strong surface patterning, and usually paler brown to red-brown seeds that are more evenly shiny and appear smooth though they are very weakly patterned.

Notes: *Calandrinia petrophila* was not included in the subgeneric classification of von Poellnitz (1934) nor in the morphological and molecular phylogenies presented by Tahir and Ashton (1989) and Hancock et al. (2018) respectively. Based on the brief morphological notes provided for each of the six clades within Australian *Calandrinia* recovered in the Hancock et al. (2018) study, the placement of *Calandrinia petrophila* is equivocal. The 4-valved capsules would suggest its membership of clade 6, which aligns with section *Basales* but species in that group have six or more petals and usually numerous stamens. Molecular sampling may help to resolve its placement.

Limited observations suggest that the capsule, subtending sepals and pedicel often fall as a unit, sometimes with seeds still within the capsule.

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New species and taxonomic changes in the *Grevillea thelemanniana* Group (Proteaceae: Grevilleoideae: Hakeinae) from south-west Western Australia

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Abstract

Four species are added to the *Grevillea thelemanniana* Group, the constituency of which is discussed in light of recent phylogenetic analyses. Two new species are described. *Grevillea cooljarloo* Keighery and Olde was previously included by some in *Grevillea preissii* Meisn. subsp. *preissii* or as *G. pinaster* divided-leaf form, and is presently known informally as *Grevillea thelemanniana* subsp. Cooljarloo (B.J. Keighery 28B) by the Western Australian Herbarium. *Grevillea gillingarra* Olde and Keighery has previously been confused with *G. thelemanniana* Hügel ex Endl. *Grevillea preissii* subsp. *glabrilimba* Olde and Marriott is here recognised at specific rank, as *G. glabrilimba* (Olde and Marriott) Olde. *Grevillea preissii* is more narrowly circumscribed, in line with the original concept *sensu* Meisner (1845), without subspecies. A photo of the Blaschka glass model of *Grevillea preissii* is included with permission. The historical confusion between *G. thelemanniana.* and *G. preissii* is revisited. *Grevillea variifolia* subsp. *bundera* Keighery is recognised at species-level as *G. bundera* (Keighery) Olde and Keighery. A conservation assessment for all taxa is provided and a key to the revised *Thelemanniana* Group, as currently accepted, is supplied.

Introduction

The taxonomy around *Grevillea thelemanniana* Hügel ex Endl. and associated species currently included in the *Thelemanniana* Group *sensu* Makinson (2000) (Group 14 *sensu* Olde and Marriott 1994) is complex. It has been confused partly by the close relationships of many recognised species, partly by changing species concepts and partly by the attempts of taxonomists to embed perceived relationships in the nomenclature based on untested hypotheses regarding morphological similarity. Recent phylogenetic studies in *Grevillea* (Holmes *et al.* 2009, 2014; Mast *et al.* 2015; Hevroy 2016) have demonstrated that morphology can be an unreliable guide to relationships. For this reason, we take the view that species recognition should follow that advocated under the Phylogenetic Species Concept and be based in the first instance on morphologically irreducible, fully diagnosable populations that can be sampled and tested at any time, and to which data-sets can be added and boundaries refined if needed (Gao *et al.* 2019).

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The operational definition of a phylogenetic species, given by Grubb and Groves (2011: 1) is similar. They treated species as 'the smallest population or aggregation of populations with heritable differences from other such populations or aggregations'. Here, we recognise such populations in the *Thelemanniana* Group as co-equal, distinct morpho-species. Irreducible species are the basic unit of evolution. Their genealogy can be traced and their relationships can be discovered by DNA testing and analysis. Although the species boundary may be undergoing expansion due to ongoing divergence, the concept of irreducibility is preferable to one in which allopatric populations that can be distinguished and diagnosed morphologically are added to the species concept to produce polytypic species, such as that tolerated under the Biological Species Concept.

Most existing subspecies of *Grevillea*, being populations fully diagnosable by morphological discontinuity, are actually closely related species under a phylogenetic model. In this context, subspecies may need re-definition. They should pass a rigorous test of relationship and certainty, but they mostly rely on untested assessments of morphological similarity. Only populations with a high degree of morphological overlap will be treated as subspecies in future, and even then we recognise that further investigation may provide evidence of full diagnosability that would enable their recognition as closely related species. An Integrative approach, succinctly outlined and updated by Hevroy (2016), following the unified concept of De Queiroz (2007) and others, is therefore supported strongly here. In recognising existing subspecies at specific rank, we have preferably used the same epithet, although this is not always possible, to provide continuity and to minimise disruption to names.

The taxonomic and horticultural history of the *Thelemanniana* Group is labyrinthine. On May 1 1839, Endlicher (1839: 6) published a description of *G. thelemanniana,* utilising a plant in Baron Karl von Hügel's garden at Heitzing, Austria. According to the protologue, it had been grown from seeds, probably sent back ['*allatis*'], or possibly brought back from south-west Western Australia (Endlicher 1839). Endlicher described his specimen as coming from a shrub about the size of a human, from which we conclude that the cultivated holotype was at least three years old or older. Even if von Hügel had sewn seed and planted germinated seedlings soon after his return from travels in 1837, the plants could not have reached this size by May 1839. Therefore, we conclude that he must have sent the seeds back, either to his sister or head gardener, sometime after he had collected them in 1833. Ducker (1900: 300) records von Hügel's enthusiasm for seed collection. The collection of seed for his garden formed part of his travel intentions, according to Clark (1994).

The holotype of *Grevillea thelemanniana,* if one ever existed, is lost and has not been located by any author. Although Endlicher failed to mention the diagnostic presence of simple leaves that are almost always intermixed with its divided leaves, McGillivray and Makinson (1993: 444) were able to unambiguously apply the name *G. thelemanniana* to known populations near the current city of Perth, Western Australia and select a neotype. Von Hügel probably only gathered a few seeds when he was there in 1833, sufficient for a single germination event, which occurred before his return. *Grevillea thelemanniana* is a rare, lignotuberous/seed-facultative species that sets very few seeds. Whether or not seed-obligate populations once occurred around Perth cannot be ascertained but we consider it unlikely.

Just a few weeks after Endlicher's publication, and apparently unaware of it, Lindley (July, 1839) also described '*G. Thelemaniana*' (sic!), citing correspondence with von Hügel about a plant 'with narrow pinnatifid leaves' 'that had recently been raised' in his garden. Although Lindley provided a Latin diagnosis that differed only in its brevity from Endlicher's, he did not cite, and may not even have seen, a specimen. There is no specimen in his herbarium at CGE. The epithet is in honour of Carl Friedrich Thelemann (1811–1889), and the abbreviated description may have also been supplied to him by von Hügel. It is presumed that the same cultivated plant was the source of both Endlicher's and Lindley's descriptions, and that therefore Lindley's treatment is *nomen superfluum, orth. var.*

According to Pfister (1889), Thelemann was recruited by von Hügel from England where he was working with Australian plants. Then a young man in his mid-twenties, Thelemann worked for von Hügel during the mid-1830s until he was appointed garden architect at the Botanical Garden in St. Petersburg in 1839. He gained horticultural experience and honed his skills, said to be 'exceptional', with von Hügel. He was possibly head gardener or in charge of his Australian collections at some point. It seems probable that he had a pivotal role in the introduction and cultivation of the eponymous *G. thelemanniana*.

Between 1839 and 1845 von Hügel distributed seedling or cutting-grown propagules under the name *G. thelemanniana* or similar, to nurserymen, aristocrats, botanic gardens and horticultural enthusiasts throughout Europe. The Frankfurt father and son, nurserymen, Sebastian Rinz and Jacob Rinz (1839: 31) first listed '*G. thelemaniana*' (sic!) for sale in their 1839–40 catalogue at the relatively high price of 12 fl. (*cf.* other *Grevillea* species listed at 1–5 fl., and one listed as 'species (*v. Hügel*)' for 20 fl.). It cannot be assumed that these plants are true to type. Rinz and Rinz (1842: 31) first publicly recognised a difference in the plants by listing *G. thelemanniana* (syn. *G. absintif.*.). Heynhold (1846: 275) indicated that *G. absinthifolia* was a synonym of *G. thelemanniana*, citing '*Hort. Belgique*', but again, *G. preissii* is implicated because there can be no obvious

reason why there should be two names for the same taxon and none for the arguably more attractive plants ultimately named as *G. preissii*. Rovelli Brothers (1861), Italian nurserymen, listed both 'G. absynthifolia' and 'G. thellemannii' (sic!) clearly affirming two separate species.

In 1842, *G. thelemanniana* was being cultivated in the garden of the Royal Belgian Horticultural Society in Brussels, according to La Société Royale Belgique (1842: 26), from where plants were also sold to order. However, Jacques (1843: 191) also described a plant in the garden of M. Martine in Paris, one of seven that had been sent by 'M. le baron *Eugel*', called 'G. tellemani brillante; [syn.] G. tellemani splendens'. From the leaf description, 'diversement divisées en lobes filiformes…pointus' this is likely to have been *G. preissii*. De Noter (1909: 33) indicated that the name *G. splendens* Hort. was also a synonym of *G. preissii*. Taking all evidence into account, 1842 marks the probable year of the introduction of *G. preissii* to horticulture. However, it seems likely that when Endlicher (1842: 288) recorded *G. thelemanniana* in the University Garden at Vienna that confusion with *G. preissii* had not become an issue there.

LeMaire (1845) published a treatment of *G. thelemanniana,* as one of a number of new or little-known, useful ornamental plants. The description and illustration, which were based on a plant growing in a green house in the French National Museum, clearly identify it as *G. preissii* Meisn. According to LeMaire, it had been raised from seed received from south-west New Holland by von Hügel in 1838 and plants propagated from it were distributed to various European gardens. LeMaire listed three European nurseries who had it for sale. The confusion between the two closely related species, *G. thelemanniana* and *G. preissii,* dates from this time, though *G. preissii* was not actually described until 1845, so the confusion is understandable.

Rudolf Blaschka (1857–1939) supplied an exquisite glass model of *G. preissii,* being at the time cultivated near Dresden, Germany, to Harvard University which he created in 1913, as '*G. thelemanniana* syn. *G. preissii* Meissn'. The model employs a degree of artistic licence in its variable depiction of petaly but is otherwise a technically accurate portrayal (Fig. 1).

Fig. 1. *Grevillea preissii* glass model created by R. Blaschka (1913). Photo by Julie L. McIntosh for the Ware Collection of Blaschka Glass Models of Plants, Harvard University, Cambridge, Massachusetts, USA. Published with permission.

In describing *G. preissii*, it seems apparent that Meisner (1845) did not see a type specimen of *G. thelemanniana* because that species would be the most obvious comparator. Instead, Meisner (1845: 543) treated *G. thelemanniana* as a close relative of, and comparable to, *G. lindleyana* Meisn. (= *G. wilsonii* A.Cunn.) and

in his description of *G. preissii*, Meisner (1845: 543–44) differentiated it from *G. crithmifolia* R.Br., making comparisons as well with *G. pectinata* R.Br. and *G. baxteri* R.Br., all species far more distantly related by comparison with *G. thelemanniana*. Meisner (1856: 372) continued recognition of the two species. Bentham and Fitch (1 May 1870) also treated *G. preissii* as distinct, but by October of that same year Bentham and Mueller (1870: 439) decided that it was a synonym of *G. thelemanniana*. For 116 years, indeed until 1986, this classification was accepted and *G. preissii* was 'lost' and went unrecognised formally.

McGillivray (1986: 15) reinstated *G. preissii* as *G. thelemanniana* subsp. *preissii* (Meisn.) McGill. within a conceptually broad *G. thelemanniana* comprising one autonymic and six additional subspecies, two of which had originally been named at specific rank (*G. obtusifolia* Meisn, and *G. pinaster* Meisn.). Two subspecies were novel, subsp. *delta* McGill. and subsp. *fililoba* McGill. Subsp. *hirtella* (Benth.) McGill. had previously been named by Bentham (1870: 427) as *G. pinaster* var. *hirtella*.

In their monograph of the genus *Grevillea*, McGillivray and Makinson (1993: 249–253) maintained *G. thelemanniana* as a broad species, enlarged to eight entities with the introduction of Form 'e', plus four collections unassignable to any subspecies, together with several anomalous specimens included in the descriptions of subsp. *delta*, subsp. *obtusifolia*, and subsp. *pinaster*. McGillivray and Makinson (1993: 250) justified this classification on the basis that the morphological differences between populations comprising these subspecies were slight compared with those between other related species, such as *G. stenomera* F.Muell., *G. variifolia* and *G. ripicola* A.S.George. Thus, they not only subscribed to the assumption that species should be accepted only when there is a certain unstated morphological distance between them but implied that the character values distinguishing their subspecies were hierarchical, without outlining their relative degrees of importance. McGillivray (1994) subsequently outlined his unique operational definition of species and his adherence to the principles of the Biological Species Concept (BSC) including reproductive isolation.

Olde and Marriott (1993) voiced their concerns in relation to the broad species concept being adopted by McGillivray. Olde and Marriott (1994) rejected the proposed classification in relation to *G. thelemanniana,* and some other broadly conceptualised species, and reinstated or recognised all seven subspecies of *G. thelemanniana sensu* McGillivray at species rank. They also described three additional species (*G. exposita* Olde and Marriott, *G. evanescens* Olde and Marriott and *G. humifusa* Olde and Marriott, together with one subspecies (*G. preissii* subsp. *glabrilimba*). At the time, Olde and Marriott (1994: 182) considered subsp. *glabrilimba* to be insufficiently distinct from *G. preissii* but did not cite any phylogenetic analysis. All these species plus others (15 taxa altogether) were considered intuitively and morphologically to belong to their Key Group 14 (Olde and Marriott 1994: 204).

The Thelemanniana Group

Makinson (2000) equated Group 14 with the *Thelemanniana* Group but with a revised constituency of 16 species, including two additional species, *G. acropogon* Makinson and *G. maccutcheonii* Keighery & Cranfield, and two non-autonymic subspecies, including *G. variifolia* subsp. *bundera* Keighery (18 taxa). The basis of this grouping, like that of Olde and Marriot, is entirely perceived phenotypic affinity. An updated morphological summary is provided by Makinson (2000), but although the *Thelemanniana* Group is comprised of species thought likely to stem from the same lineage, no single character has been identified as a potential synapomorphy. However, species phenetically closest to *G. thelemanniana sensu* McGillivray and Makinson (1993) have numerous potential synapomorphies including the ovary transversely to obliquely truncate at base and with a variably prominent suprabasal ridge or anterior heel, the gynophore conspicuous, compressed, concavo-convex, follicles cylindrical-trianguloid with a thin, rugose pericarp, and seeds with a downy coat.

The time-calibrated phylogeny inferred for subtribe Hakeinae from five genetic regions (4 plastid and 1 nuclear) combined by Mast *et al.* (2015) suggested that the *Thelemanniana* Group was not monophyletic and needed revision. In that study, the two tested species (*G. acropogon* and *G. preissii* subsp. *preissii*) were not resolved as sister, although both were resolved in the same large heterogeneous clade (Clade 4) of mainly simple-leaved species, with a crown age of *c.* 35 million years. *Grevillea acropogon* was nested in a more recently evolved subclade with a crown age of 5–7 million years that also contained the two species from Group 16 (the *Hakeoides* Group). *Grevillea preissii* was resolved as sister to a subclade comprising species from several Groups.

In a more focussed phylogeny restricted to the *Thelemanniana* Group *sensu* Makinson, inferred from two plastid genes and 12 nuclear microsatellites, Hevroy (2016) also found that the *Thelemanniana* Group was not monophyletic. Using molecular methods and dating technology, she found that there was a significant lineage divergence within the *Thelemanniana* group, dating back to the Miocene (5–20 Myr). All the southern species (*G. acropogon, G. maccutcheonii* and *G. ripicola*) were resolved with two outgroup species in the *Hakeoides* Group with similar southern distributions. Hevroy also stated that species recognition was warranted for two

unique lineages identified by both cpDNA sequences and nDNA microsatellite data, viz. *G. cooljarloo* Keighery & Olde and *G. gillingarra* Olde & Keighery, both described below.

Although the results published by Hevroy suggest that the constituency of the *G. thelemanniana* Group should be divided along geographic lines, the species composition remains uncertain because another member of the *Hakeoides* Group, *G. commutata* F.Muell., was resolved with the remaining species in the northern lineage. This suggests, among other things, that there is a complex, unresolved relationship, with the *Hakeoides* Group more broadly and also the *Linearifolia* Group, both of which are paraphyletic with respect to the *Thelemanniana* Group in the study published by Mast *et al.* (2015). Indeed, *G. olivacea* might be more closely related to *G. commutata* than to *G. thelemanniana* (see also comments by Makinson 2000: 163). The ultimate grouping of species awaits results from a more comprehensive phylogenetic analysis of the whole genus currently led by Professor M. Cardillo (ANU) and collaborators, which has been delayed by the Covid-19 pandemic. Accordingly, we have not made any changes here to the constituency of the *Thelemanniana* Group, which now includes 20 species, pending the results of that study. Further, although taxonomic studies of the *Hakeoides* and *Linearifolia* Groups are ongoing, they are not well-advanced. However, a preliminary morphological overview supported by results published by Hevroy 2016 indicates that additional new species await recognition. In particular variation in *G. pinaster* warrants further study.

Morphology

In this paper and from now on we refer to the *floral rachis* as the *inflorescence rachis* since the flowers strictly speaking do not have a rachis. The term *single-stemmed* replaces the term *stenobasic* which, since its introduction in 1993, has not achieved widespread currency. The term *simple inflorescence* replaces the term *unit conflorescence,* which likewise has not achieved widespread usage. The distance between the proximal leaf lobes (divided leaves) and the branchlet has diagnostic value in several groups. Here and from now on, we refer to this area of the leaf rachis as the *basal rachis node*. The term *floral bracts*, which are widely accepted as bracts that subtend individual flowers, strictly do not occur in *Grevillea.* The term, in recent treatments, has been replaced by the term *common bracts*, which individually subtend flower pairs.

Key to species in the *Thelemanniana* Group (widely distributed from the Exmouth area to Lake Unicup, N of Frankland)

1 Leaf bases amplexicaul (E of Ludlow to Hithergreen) ..... ***G. maccutcheonii***

1: Leaf bases linear to cuneate **2**

2 Leaves divaricately divided, the principal leaf rachis angularly refracted at first and/or terminal node **3**

3 Pistils 29–35 mm long; leaf rachis refracted at first node; outer surface of perianth glossy *in vivo*; leaf lobes 1.5–5 mm wide, linear to elliptic, the under-surface exposed, glabrous; simple leaves sometimes present; intramarginal veins evident on leaf upper surface (Collie to Bridgetown) ..... ***G. ripicola***

3: Pistils 20–22 mm long; leaf rachis angularly refracted at all nodes; outer surface of perianth dull *in vivo*; leaf lobes 0.8–1.1 mm wide, linear, the under-surface enclosed by margins when dry, sericeous in the grooves beside the midvein; simple leaves never present; intramarginal veins not evident on leaf upper surface (near Lake Unicup) ..... ***G. acropogon***

2: Leaves flat or secund, the principal leaf rachis straight or smoothly recurved **4**

4 All or some leaves divided **5**

5 Leaves coarsely divided, obovate or obtrullate to subcruciform; leaf base cuneate; venation conspicuously raised on the leaf upper surface **6**

6 Leaves 1.7–4.3 cm long, pliable, silvery, obovate, the apex obtuse, apically dentate or shallow-lobed in the distal half; leaf lobes linear to narrow-triangular; petioles 3–6 mm long; conflorescences usually branched (Cape Range) ..... ***G. variifolia***

6: Leaves 1.0–1.5 cm long, rigid, grey, subcruciform, the apex acute, pungent, the lobes broad-triangular; petioles *c.* 2 mm long; conflorescences mostly simple (inland from Ningaloo) ..... ***G. bundera***

5: Leaves deeply divided, usually with sub-sect division; leaf base linear to very narrowly cuneate; venation obscure to evident on the leaf upper surface **7**

7 Conflorescence development acropetal (floral buds enlarging first from base of the rachis towards the apex) **8**

8 Inflorescence rachises glabrous (rarely with scattered isolated hairs); perianth limb and pedicels glabrous (coastal and subcoastal; Leeman to Cervantes) ..... ***G. glabrilimba***

8: Inflorescence rachises densely hairy; perianth limb and/or pedicels hairy or glabrous **9**

9 Distance from basal leaf lobe to branch 1–4 mm; branchlets densely hairy **10**

10 Simple inflorescence rachises mostly 20–50 mm long; habit of plant prostrate with elongate branches to 3 m long; branchlets densely tomentose, lacking conspicuous long hairs to 2 mm long interspersed; leaves grey; perianth glabrous with scattered appressed hairs confined to the limb (SE of Jurien Bay) ..... ***G. humifusa***

10: Simple inflorescence rachises mostly 8–15 mm long; habit of plant shrubby with ascending branches < 1 m long; branchlets densely tomentose with conspicuous long hairs interspersed; leaves green; perianth glabrous or sometimes variably and sparsely hairy (Mt Lesueur area) ..... ***G. delta***

9: Distance from basal leaf lobe to branch > 5 mm; branchlets glabrous to sericeous-tomentose **11**

11 Branchlets with a dense indumentum; leaves 2.5–5.2 cm long, divided, very rarely an occasional leaf simple; perianth outside (including below the limb), and pedicels, with few to many appressed hairs; inflorescence rachises densely tomentose (coastal and subcoastal; Lancelin–Yalgorup) ..... ***G. preissii***

11: Branchlets glabrous or sparsely hairy; leaves 0.8–3.2 cm long, simple and divided; perianth outside and pedicels glabrous, (appressed hairs confined to the perianth limb); inflorescence rachises sparsely sericeous (Cooljarloo area) ..... ***G. cooljarloo***

7: Conflorescence development basipetal (floral buds enlarging or opening first at the apex of the rachis) to synchronous **12**

12 All or some leaves with secondary and/or tertiary partite (-sect) division; leaf apices acute or obtuse **13**

13 Conflorescence subglobose-secund, lax; styles drooping; pistils 24–28 mm long; pollen-presenter 1.4–1.8 mm long; branchlets glabrous; widest leaves > 2 cm wide; leaf lobes 0.3–0.5 mm wide, filamentous, curved, terete, pliable; perianth 3–4 mm wide, often glaucous (Greenough River to Ellendale Pool) ..... ***G. fililoba***

13: Conflorescence subcylindrical-secund, tight; styles spreading; pistils 20–22 mm long; pollen-presenter *c.*1.2 mm long; branchlets pilose; widest leaves ≤1.5 cm wide; leaf lobes 0.6–0.8 mm wide, not filamentous, straight, linear, stiff; perianth 2.2–2.5 mm wide, non-glaucous (Gillingarra area) ..... ***G. gillingarra***

12: All leaves either once-divided or once-divided leaves and simple leaves intermixed **14**

14 Inflorescence rachises 35–60 mm long; leaf margins angular; all leaves silvery-grey, pinnately divided; leaf lobes 4–12.5 cm long; pedicels and perianth outside densely to sparsely hairy (Kalbarri to Tamala) ..... ***G. stenomera***

14: Inflorescence rachises < 25 mm long; leaf margins smoothly revolute or recurved; all leaves green or bluish-green, either simple or if divided then intermixed with simple leaves); leaf lobes of divided leaves < 4 cm long; pedicels and perianth glabrous (the limb sometimes with appressed hairs) **15**

15 Branchlets pubescent, tomentose or villous (hairs spreading) **16**

16 Upper surface of leaves punctate or with spreading hairs; lower surface and sometimes also the midvein enclosed by strongly and often unevenly revolute margins; perianth limb flanged at the segment interfaces (between Mingenew to Walkaway) ..... ***G. hirtella***

16: Upper surface of leaves smooth, glabrous; lower surface narrowly exposed beside midvein or enclosed and bisulcate, the midvein never obscured by margins; perianth limb smooth, without flanges at the segment interfaces **17**

17 Simple leaves (2.5–)4–8 cm long; lower surface either enclosed by revolute margins or narrowly exposed; leaf margins smoothly and evenly revolute; leaf lobes of divided leaves when present 0.5–2(–2.8) mm wide (Murchison River to Eneabba with disjunct occurrences at Hamelin Pool, Wongan Hills, Pithara)..... ***G. pinaster***

17: Simple leaves 1.3–3 (–3.5) cm long; lower surface exposed; leaf margins smoothly but loosely revolute; leaf lobes of divided leaves when present 1.2–5.5 mm wide (Eneabba, Arrowsmith to Arrino)..... ***G. exposita***

15: Branchlets glabrous, subsericeous or sericeous (hairs appressed)..... **18**

18 Simple leaves 2–4 mm wide, predominant (Pinjarra, Muchea to Gingin)..... ***G. obtusifolia***

18: Simple leaves absent or if present, then < 2 mm wide..... 19

19 Most leaves 2.5–8 cm long; lower surface of simple leaves enclosed by tightly and evenly revolute margins, rarely slightly exposed on leaves > 4 cm long; plants seed-obligate or lignotuberous (Murchison River to Eneabba with disjunct occurrences at Hamelin Pool, Wongan Hills, Pithara)..... ***G. pinaster***

19: Most leaves 1–2(–2.5) cm long; lower surface of some leaves narrowly exposed beside midvein; leaf lobes of divided leaves 0.5–1.7 cm long; plants lignotuberous (Kenwick area of Perth)..... ***G. thelemanniana***

4: All leaves simple and entire..... **20**

20 Leaf lower surface broadly exposed; leaf margins shortly recurved..... **21**

21 Outer surface of perianth hairy; simple inflorescences regular, dome-shaped (coastal from Jurien Bay to Coolimba)..... ***G. olivacea***

21: Outer surface of perianth glabrous or almost so; simple inflorescences secund..... **22**

22 Lower surface of mature leaves densely sericeous; plants prostrate to 3.5 m high, lignotuberous, their width greater than their height; leaves 2–4 mm wide..... **23**

23 Branchlets sericeous to glabrous (Pinjarra, Muchea to Gingin)..... ***G. obtusifolia***

23: Branchlets pubescent-tomentose (Eneabba–Arrowsmith River to Arrino)..... ***G. exposita***

22: Lower surface of mature leaves glabrous, rarely a few hairs scattered; plants tree-like 3–5 m high, seed-obligate, their height > than their width; leaves 2.5–9 mm wide (Yanchep to Neeragabby)..... ***G. evanescens***

20: Leaf lower surface either fully enclosed by leaf margins or partly visible in narrow grooves beside the midvein; leaf margins revolute, abutting the midvein on the under-surface or almost so..... [back to] 19

Taxonomy

1. *Grevillea cooljarloo* Keighery and Olde, **sp. nov.**

Type: Western Australia: Woolka Rd., 10 km W of intersection with Cooljarloo Rd, *G.J. & B.J. Keighery 917*, 22 Sep 2006 (*holo*: PERTH07851790; *iso*: MEL; NSW) (*distribuendi*).

Grevillea pinaster 'Pinnate-leaf form' *sensu* Olde & Marriott (1995b: 98) in part.

Grevillea preissii 'Palgarup Springs' Hort.

Grevillea thelemanniana subsp. Cooljarloo (B.J. Keighery 28 B). Western Australian Herbarium (1998–), in *FloraBase*, https://florabase.dpaw.wa.gov.au/browse/profile/48402 [accessed Dec 2016]

Grevillea sp. Cooljarloo (B.J. Keighery 28 B). Western Australian Herbarium (1998–), in *FloraBase*, https://florabase.dpaw.wa.gov.au/browse/profile/48402 [accessed 5 Dec 2021]

Differs from *Grevillea preissii* in its branchlets glabrous or almost so versus densely sericeous-tomentose, its leaves generally shorter (0.8–3.2 cm long versus 2.5–5.2 cm long) and with usually shorter basal rachis node 5–11 mm long versus 9–20 mm long, the ultimate lobes 5–10 mm long versus 10–27 mm long; its inflorescence rachises 10–22 mm long versus 20–40 mm long; its perianth below the limb glabrous versus sparsely sericeous.

Seedlings not seen. *Mature plants* lignotuberous, seed-facultative, spreading, multi-stemmed shrub 0.3–0.5(–0.7) m high, 0.5–1.5 m wide, with spreading to ascending branches from the trunk near to the

ground. *Branchlets* 0.8–1.2 mm thick, terete to slightly angular, a raised glabrous rib sometimes decurrent from leaf bases, yellowish, glabrous to openly sericeous-tomentose, rarely densely tomentose-villous. *New growth* sericeous or sparsely so. *Adult leaves* simple and divided (usually both together), 0.8–2.2(–3.2) cm long, ascending, subsessile to shortly petiolate, mid to dark green, subglabrous; *simple leaves* 0.7–0.8 mm wide, linear, straight or slightly curved; *divided leaves* 4–10 mm wide, trisect to pinnatisect, secondary bi- or trisect division of primary lobes rare, more common in young plants where some tertiary division also evident (Olde *et al*. 15/99a) imparipinnate, secund, petiolate; *primary leaf lobes* (2–)3–4(–5); *basal rachis node* (divided leaves) 5–11(–13) mm long, 0.8 mm wide, linear, straight or recurved; *ultimate lobes* (2–)5–10(–23) mm long, 0.6–0.9 mm wide, linear, straight, the terminal lobe sometimes bipartite; *apices of leaves and lobes* subacute to obtuse-mucronate, the mucro *c*. 0.1 mm long, blunt, non-pungent; *adaxial surface* smooth or with scattered punctae, transversely convex or flat, glabrous, rarely with scattered appressed hairs, the venation obscure, the midvein impressed; *margins* smoothly revolute, tightly and evenly enclosing the abaxial surface except the midvein; *abaxial surface* bisulcate, the lamina enclosed by margins, the sulcae very narrow, usually glabrous, the midvein prominent; *texture* coriaceous; *petioles* 0.1–2.5 mm long, 1–1.2 mm wide, spreading slightly at the point of attachment, glabrous. *Conflorescences* terminal or subterminal, simple, erect on decurved peduncles or deflexed, secund, acropetal; *buds* narrow-ellipsoid, soon cylindrical, sericeous, subsessile to shortly pedunculate; *peduncles* (1–)2–5 mm long, decurved, sparsely to densely sericeous; *rachises* 10–22 mm long, 0.3–0.6 mm wide, sparsely to moderately densely sericeous, straight, with an erect caudate extension 0.5–1 mm long; *common bracts* 0.3–0.5 mm long, ovate with incurved apex, sparsely sericeous on the outer surface, caducous. *Pedicels* 5–6 mm long, 0.3 mm wide, red, glabrous or with a few scattered hairs towards the apex; *torus* 0.8 mm across, oblique at *c*. 15°–30°, squarish; *tepal attachment scar c*. 0.1 mm wide, visible above and on the toral rim; *nectary* conspicuous, cushion-like to slightly U-shaped, rising 0.4–0.5 mm above the torus, the margin 0.3 mm thick, smooth; *pistils* (21–)25–26 mm long, glabrous; *gynophore* 4–5 mm long; *ovary* 1.5 mm long, 0.8 mm maximum width at base, green, lateral, prominent, triangular, the base truncate or obliquely so, or slightly retrorse; *style* 0.4 mm wide, red, yellowish at the apex, gently incurved; *pollen-presenter* 0.8–1.2 mm long, 0.7–1 mm wide, yellow, very oblique at *c*. 70° to sublateral; *perianth c*. 6 mm long, 0.8–2 mm at base, red, the tubular section glabrous, narrowly ovoid-ventricose to oblong at anthesis, distally contracted below the revolute limb, soon deciduous and falling as a coherent unit, at anthesis, the limb segments all separated, the dorsal suture separated to base; *abaxial surface* glabrous below the limb; *perianth limb* 1 mm long, 0.5 mm wide, subcubic to depressed-globose, tightly revolute, sparsely sericeous, often minute white hair bases evident; *adaxial surface* glabrous at base for *c*. 1.5 mm, then tomentose to just below the curve, condensed into a beard above half-way along on the ventral tepals, glabrous elsewhere except along the tepal margins which are papillose-hairy. *Follicles* and *seeds* not seen. (Fig. 2)

Diagnostic characters: Lignotuberous growth habit; branchlets terete, glabrous to sparsely sericeous-tomentose; new growth glabrous or sparsely sericeous; leaves simple and divided (both present usually), 0.8–3.2 cm long; leaves and leaf lobes linear, bi- or trisect or pinnatisect with 3–5 pairs of primary lobes; secondary bi- or tri-partite division sometimes evident; maximally divided leaves secund; ultimate leaf lobes 10–23 mm long, <1 mm wide, the under-surface of leaves and lobes tightly enclosed by smoothly revolute margins; basal rachis nodes 6–13 mm long; common bracts 0.3–0.5 mm long, ovate, early caducous; rachises 10–22 mm long, sericeous or sparsely so; pedicels 5–6 mm long, glabrous or with a few appressed hairs near the apex; pistils *c*. 25 mm long; perianth glabrous outside except for scattered hairs on the limb.

Distribution: Scattered populations in the Lesueur Sandplain Subregion of the Geraldton Sandplain IBRA Region in the Dandaragan LGA, Western Australia.

Phenology: Recorded in flower most of the year with a spring peak.

Habitat and ecology: Occurs mostly in winter-wet flats in grey sand over clay with *Banksia telmatiaea, Calothamnus, Senecio, Hakea trifurcata,* in low heath, on floodplains or around drainage lines and creeks.

Conservation status: Listed as Priority 1 by the Western Australian Department of Parks and Wildlife. However, Hevroy (2016) recommended downgrading this rating to Priority 4, given a survey of its range found large continuous populations.

Etymology: The epithet is an indeclinable noun in apposition, and derives from an Aboriginal word of the Yued or Billinue Aboriginal community relevant to the locality where the new species occurs, the precise meaning of which is uncertain.

Fig. 2. *Grevillea cooljarloo*. A. Seasonally waterlogged habitat (Wongonderrah Road). B. Decumbent to spreading habit (Woolka Road). C. Flowering branches (Woolka Road). D. Leaves and inflorescence (Wongonderrah Road). Photos: A, D: R. Barrett; B, C: P. Olde.

Variation: The collection Olde 17/37 differs from other specimens in its densely tomentose-villous branchlets. It also has more hairs on the distal section of the pedicels. This and other specimens from Pen Road may be introgressed by plants of *G. delta.* Although no evidence for introgression or hybridisation was reported by Hevroy (2016) for any included species in the Group, it is possible that plants at or near this site were not sampled.

Discussion: The informal classification of *Grevillea cooljarloo* was based on a shared ecological and morphological association with *G. thelemanniana*. It was initially phrase-named as *Grevillea thelemanniana* subsp. Cooljarloo (B.J. Keighery 28 B) by the Western Australian herbarium. However, Hevroy (2016), using sequences from only two cpDNA introns and 12 nuclear microsatellite markers designed specifically for *Grevillea thelemanniana* and cross-amplified across the *Thelemanniana* group, resolved *G. cooljarloo* as sister to *G. delta*. Both have unique cpDNA haplotypes and showed no evidence of admixture in the nuclear data. *G. thelemanniana* was resolved in a separate subclade. Hevroy showed that molecular evidence supported the recognition of *G. cooljarloo* as a distinct lineage, occupying an explicit floodplain and creek line habitat at low altitude (37–79 m asl).

Delimitation of *G. cooljarloo* here geographically expands the number of populations sampled by Hevroy from which she reported high genetic variability. Seven unique haplotypes were detected in populations from different sampling localities.

Grevillea thelemanniana differs phenetically in its basipetal inflorescence development, its simple leaves wider, and its divided leaves flat with leaf lobes lacking secondary development. The leaf margins of *G. thelemanniana* are loosely revolute and the leaf under-surface bears a narrow, sericeous laminal strip clearly visible between the leaf margin and midvein, especially noticeable on wider leaves.

Grevillea cooljarloo was included in *G. pinaster* by Olde and Marriott (1995b), as a divided-leaf form. It is still uncertain whether other collections of *G. pinaster* with divided leaves form populations or are morphological variants within populations that are mainly simple-leaved. However, *G. pinaster* differs from *G. cooljarloo* in its

basipetal inflorescence development. Divided leaves are flat and are also without secondary division. In most populations, *G. pinaster* has only simple, longer leaves (2–4 cm long).

Grevillea cooljarloo has also been confused with *G. preissii* because it (sometimes) has twice-divided leaves, acropetal inflorescence development and hairy inflorescence rachises. However, *G. preissii* [subsp. *preissii*] is distinguishable from *G. cooljarloo* by its densely tomentose branchlets, by the presence of appressed hairs on the perianth tube, by its generally longer inflorescences and by its lack of simple leaves. *G. preissii* subsp. *glabrilimba*, here recognised as a distinct species, differs in its villous branchlets, its glabrous inflorescence rachises and glabrous perianth limb. It also usually has longer inflorescences.

G. exposita differs in its densely pubescent-tomentose branchlets, its simple leaves wider (1.2–1.4 mm wide), and in its basipetal inflorescence development. Its infrequent divided leaves are never with secondary division. Recognition of this species here is based on genetic, ecological and morphological evidence, with more than one line of evidence satisfying criteria for species recognition under differing concepts.

Although it is accepted by Hevroy (2016) that there is no obvious mechanism evolved for seed dispersal beyond gravity, seed morphology in the Group generally shows clear evidence via the presence of an elaiosome, of myrmecochory (Auld & Denham 1999). However, the lack of follicles formed on a cultivated specimen at Oakdale, New South Wales, suggests that this species may not be self-compatible, only rarely seed facultative, probably long-lived and very largely reliant on a fire-tolerant rootstock as a fire defence.

Specimens seen: Western Australia: 2 km N of junction of Eneabba South Rd and Coorow–Greenhead Rd, *C. Chapman s.n.*, 28 Aug 1977 (PERTH 01845446); Woolka Rd, *c.* 10 km W of Cooljarloo Rd, NW of Cataby, *A. Crawford ADC 2602*, 24 Nov 2014 (PERTH 08721750); Corner Wonganderrah and Munbinea Rds, Jurien Bay, *K. Himbeck KJH 1*, 8 Sep 2008 (PERTH 08709580); 8 km along Cantabilling Rd from Mumbinea Rd, 20 km SE of Jurien Bay, *G.J. & B.J. Keighery 1562*, 27 Jul 2009 (PERTH 08461651); West Mumbinea Rd at junction of Munbinea and Wonganderrah Rd, *B.J. Keighery 28B*, 11 Jun 1988 (PERTH 01109138); N. side of Woolka Rd, c. 8 km W of junction with Cooljarloo Rd, *B.J. Keighery 544B*, 5 Nov 1988 (PERTH 01109146); Woolka Rd, NW of Cataby, *B. Loudon & S. Coultas BLSC* – Opp 6, 10 Oct 2012 (PERTH 08564779); Woolka Rd, NW of Cataby, *J. Milner & S. Hines 283-04*, 12 Oct 2012 (PERTH 08564760); Cantabilling Rd, 10.6 km east of Munbinea Rd, *P.M. Olde* 99/55, 9 Oct 1999 (NSW 534590); Pen Rd, 0.8 km N of Coorow–Greenhead Rd, *P.M. Olde* 99/64, 10 Oct 1999 (NSW 534494, CANB, PERTH); Woolmulla Rd, east of Cockleshell Gully Rd, *P.M. Olde* 99/69, 10 Oct 1999 (NSW 534603, PERTH); Woolka Rd, 10.6 km west of Cooljarloo Rd, W of Cataby, *P.M. Olde* 15/99, *R.F. Brown & G. Meiklejohn*, 29 Aug 2015 (CANB, MEL, NSW, PERTH); Pen Rd, 0.7 km N of Coorow–Greenhead Rd, *P.M. Olde* 15/106, *R.F. Brown & G. Meiklejohn*, 30 Aug 2015 (AD, CANB, HOB, MEL, NE, NSW, PERTH); Cantabilling Rd, 100–200 m W of Black Arrow Rd, 8 km E of Munbinea Rd, *P.M. Olde* 17/36 *& K. Alcock*, 3 Sep 2017 (BRI, CANB, MEL, NSW, PERTH (distribuendi); Pen Rd, 0.8 km N of Coorow–Greenhead Rd, west of Half Mill Roadhouse, *P.M. Olde* 17/37 & *K. Alcock*, 3 Sep 2017 (AD, CANB, HO, MEL, NSW, PERTH, WELT); 10 km SE of the Pinnacles, *R. Orifici LE 6.15*, 27 Oct 1999 (PERTH 06378498); 21.5 km W along Cantabilling Rd, from Brand Highway, just west of creek crossing, *S. Patrick 1250*, 22 Sep 1992 (PERTH 07276079).

2. *Grevillea gillingarra* Olde and Keighery, **sp. nov.**

Type: Western Australia: on Mogumber to Moora Road [Precise locality withheld for conservation reasons], *G.J. & B.J. Keighery 1063*, 3 Sep 2007 (holo: PERTH 08570078; iso: CANB; K; MEL; NSW; PERTH 08570132) (distribuendi)

Grevillea sp. Gillingarra *R.J. Cranfield* 4087 in Western Australian Herbarium (1998–) https://florabase.dpaw.wa.gov.au/browse/profile/31354 (accessed 5 Dec 2021)

Differs from *Grevillea thelemanniana* in its taller and more open seed-obligate habit, its branchlets sharply angular and with a spreading indumentum, its new growth openly pilose, its leaves with secondary and sometimes with tertiary division, never simple, the under-surface fully enclosed by tightly revolute margins, its more conspicuous exposed conflorescences, its longer inflorescence rachises , and longer-persistent common bracts.

Seedlings not seen. *Mature plants* single-stemmed, seed-obligate, open, spreading, dark green *shrubs* (0.5–)1.5–1.8(–2.2) m high, 0.5–1.5 m wide, with ascending branches from the trunk near to the ground; *branchlets* 0.8–1.2 mm wide, angular, usually reddish, loosely villous or sometimes a few hairs scattered. *New growth* initially densely white-sericeous, soon sparsely to moderately densely pilose to subvillous. *Adult leaves* divided, 1.0–2.2(–3.2) cm long, 15–20 mm wide, ascending to suberect, dark green, subglabrous with scattered hairs spreading, bipinnatipartite, rarely bi- or tripartite, sometimes with bi- or tripartite tertiary division of one or more ultimate lobes, imparipinnate, secund, sessile; *primary leaf lobes* (2–)4–8; *basal rachis node*

(4–)5–12 mm long, linear, straight; *ultimate lobes* 0.2–1.2 cm long, 0.6–2.0 mm wide, linear-oblong to narrow-obovate, straight, often unequal; *apices of lobes* obtuse-mucronate, the mucro 0.1–0.2 mm long, recurved with a reddish-brown callous point; *adaxial surface* smooth, transversely convex or bi-convex, glabrous or with scattered spreading hairs, venation obscure, the midvein within an impressed midline groove; *margins* smoothly but loosely revolute, abutting or sometimes overtopping the midvein, obscuring the abaxial surface when dry, but the lamina narrowly exposed in a sericeous strip; *abaxial surface* bisulcate, the lamina obscured except occasionally at the proximal lobe sinuses, the sulcae very narrow, sometimes with a few appressed hairs, the midvein prominent; *texture* coriaceous; *petioles* obscure. *Conflorescences* either simple and pedunculate, or rarely 1-branched at base and sessile, terminal, subterminal on short side branches, or axillary, pedunculate; *buds* cylindrical, tomentose; *simple conflorescences* 2–4 cm long, decurved, subcylindrical to subsecund, the flowers loose to moderately condensed, 30–40-flowered, usually exceeding the foliage, basipetal; buds subcylindrical, pedunculate; *peduncles* 6–12 mm long, sparsely to moderately densely sericeous-tomentose; *rachises* (15–)20–40(–50) mm long, 0.8 mm wide, straight or curved, densely sericeous-tomentose; *rachis extension* 2–2.5 mm long, linear, erect or incurved distally, densely subsericeous; *common bracts* mostly 0.3 mm long, 0.3 mm wide, ovate, sericeous-tomentose on the abaxial surface, glabrous adaxially, variably persistent to anthesis, the proximal (?involucral) bracts sometimes to 2 mm long, ovate-acuminate. *Pedicels* 4–4.5 mm long, 0.3 mm wide, usually with a few appressed hairs, dilated below the torus to *c.* 1 mm wide; *torus* 0.8–1 mm wide, transverse to oblique at *c.* 10°, squarish; *tepal attachment scar* 0.1 mm wide, situated above or coincident with the toral rim; *nectary* yellow, conspicuous, cushion-like, rising 0.5–0.6 mm above the torus, thick; *pistils* 20–22(–23) mm long, glabrous; *gynophore* 3–3.5 mm long; *ovary* 1.3 mm long, *c.* 1 mm wide, lateral, prominent, triangular, the base truncate, obscurely ridged; *style* 0.35 mm wide, red, strap-like, gently incurved; *pollen-presenter c.*1.2 mm long, 1.2–1.3 mm wide, green to yellow, almost round, lateral to oblique at *c.* 70°; *perianth* 7–8 mm long, 2.2–2.8 mm maximum width, red, narrowly ovoid, tapering below the limb, glabrous outside except the limb, glabrous inside at base for *c.* 1.5 mm then sparsely tomentose for a few mm, the hairs short, simple, becoming condensed about half way along adjacent to the ovary, the tepal margins with short simple hairs, the adaxial surface glabrous distally; *tepals* coherent except along the dorsal suture, the tepal-limb segments separating and curling down after anthesis, the perianth falling as an entire unit; *perianth limb* 1.3 mm long, 1 mm wide, spheroidal with depressed apex or ovoid with short central apiculum, revolute, sparsely sericeous. *Follicles* and *seeds* not seen. (Fig. 3)

Fig. 3. *Grevillea gillingarra* (type location). A. Flowering branches. B. Leaves and inflorescences. Photos: P. Olde.

Diagnostic characters: Shrub, seed-obligate; cauline and foliar indumentum spreading, soon sparse; new growth pilose to subvillous; branchlets angular; leaves 1.5–2 cm long, divided, pinnatisect with 2–5 primary lobes, the primary lobes 0.8–1.4 mm wide, frequently with secondary division; basal rachis node 6–12 mm long; upper surface of leaf lobes smooth the venation obscure; margin smoothly revolute loosely enclosing the lower surface when dry; *conflorescences* decurved, subsecund to subcylindrical, basipetal; rachises (15–)20–40(–50) mm long, silky-tomentose; common bracts minute, variably persistent; pedicels 4–4.5 mm long, glabrous; pistils 20–23 mm long, glabrous; pollen-presenter 1.2 mm long; perianth outside glabrous except for the limb sparsely sericeous, the inner surface pubescent-tomentose.

Distribution: Western Australia, where confined to a small population north of the Moore River bridge. It occurs in the Victoria Plains LGA, in the Dandaragan Plateau–Northern Jarrah Forest Subregion of the Jarrah Forest IBRA Region.

Phenology: Flowers in August–September with sporadic flowering outside this period.

Habitat and ecology: Grows along an ephemeral creek line in red-brown stony clay-loam in *Allocasuarina huegeliana-Eucalyptus wandoo* woodland, sometimes known as kwongan. Associated species include *Isopogon dubius, I. divergens, Banksia kippistiana, Daviesia* sp., *Leptospermum erubescens, Grevillea pilulifera, Dampiera alata, Persoonia* sp., *Acacia pulchella, Baeckea crispifolia.*

Etymology: The epithet alludes to the town near which this species occurs. It is a non-declinable noun in apposition.

Conservation status: When first collected and recognised as a new species in 2007, *G. gillingarra* was estimated (label data PERTH08570078) to have a population of 'more than a hundred plants'. Although an assessment of numbers needs a proper survey, the population was less than 30 when surveyed in 2015, following illegal vehicular intrusion and soil dumping on the site. In the most recent survey (August 2022) by the authors there were only 8 plants alive. The Western Australian Species and Communities branch of DBCA have given a conservation rating of Threatened. According to the Department of Parks and Wildlife (2016) the species faces threats from rail maintenance, weeds, fire, low population size, insecure land tenure, poor recruitment, climate change including drought but immediate direct intervention is strongly recommended.

Discussion: *Grevillea gillingarra* has been regarded as a form of *G. thelemanniana. Grevillea thelemanniana* differs in its low habit, its lignotuberous, seed facultative, generative habit, its leaves often simple, more pliable, and the leaf under-surface narrowly exposed beside the midvein Its divided leaves are more or less flat and with primary division only. *Grevillea thelemanniana* also has shorter inflorescence rachises (5–15 versus (15–)20–40(–50) mm long), and more enclosed (less exserted) conflorescences. *Grevillea preissii* differs in its lignotuberous habit, its leaves longer (2.5–5 cm long) and softly pliable, its conflorescences acropetal, conical-secund, the perianth below the limb sparsely to moderately densely sericeous on the outer surface, and the perianth limb more densely sericeous.

G. cooljarloo is also a lignotuberous shrub and usually also has some simple leaves intermixed with divided leaves. It differs also in its branchlet and foliar indumentum appressed or glabrous, and in having shorter inflorescence rachises (10–15 mm long).

Hevroy (2016) found that *G. gillingarra* clearly constituted a distinct lineage and deserved formal recognition at specific rank. It was resolved in a clade comprising northern members of the *Thelemanniana* Group. It also occupies a unique soil type that is apparently not underlain by a calcareous layer, as only one population has been located despite all vegetated reserves (both State and Local Government) in the Mogumber to Moora area being searched. Its potential habitat range is difficult to assess.

Specimens seen: Western Australia: [Precise localities withheld] *L. Canackle LCH007*, 11 Sep 2013 (PERTH 08738653); *R.J. Cranfield* 4087, 17 Sep 1983 (PERTH 01845411); *A. Crawford ADC 2375*, 14 Oct 2013 (PERTH 08597960); *K. Himbeck KJH 43*, 16 Sep 2008 (PERTH 08709440); *S. Patrick 571*, 9 Jul 1991 (PERTH 01882503).

3. ***Grevillea preissii*** C.F.Meisner, *in* J.G.C. Lehmann [ed.], *Pl. Preiss.* 1: 543–4 (1845). *Grevillea thelemanniana* subsp. *preissii* (Meisn.) McGill., *New Names in Grevillea* 15 (1986); *Hakea dixoniana* Christenh. & M.W.Chase, *Global Flora* 4: 79 (2018).

Type citation: [Western Australia] In solo calcareo ad latus montis Elizamountain, Perth d. 19 Mai 1839. Herb. Preiss. No. 709.

Lectotype chosen by McGillivray & Makinson (1993: 444): 'In solo calcareo ad latus montis "Eliza Mountain", (Perth). Per. coccineum. Majo 19. 39 legit L. Preiss No. 709. NY 00284692 whole sheet including packet with additional barcode NY 00284693.

Isolectotypes (Preiss 382 is the same as Preiss 709, an early number with the same label data and collection date, but most were distributed as *Preiss* 709, following the arrangement in *Plantae Preissianae* (1845 & 1848): B (*n.v.)*; 'Preiss 709' BR 0000013462239 ex Hb. Martius; '382 Grevillea preissii Meisner, 3–5 pedalis, pulcherrima. In solo calc lat montis Eliza Swan River, 1839 5 19, Preiss' CGE 13219 - specimen at left of sheet; 'Preiss 709' G 389411 - specimen at right; G 389412 ex Hb. Boissy et Hb. Boissy-Barbier; G-DC 327655; LD 1084813 (lectoparatype *fide* McGillivray *et al.* (*loc. cit.*); HBG 508261; 'Preiss 709' K 000799248; LE -2 sheets (*n.v.*); 'Preiss 709' MEL 74845 ex Hb. Sonder; MEL 74846 ex Hb. Sonder; MEL 74847 ex Hb Sonder; 'Preiss 709' MO 100481287 (*n.v.*); '709 Grevillea preissii Meisn Australia occidentali Vendid. Preiss 1844'P 03354160 ex Hb. Lenormand ex Hb. Cadomense; '709 legit 19 Mai 1839 et communicavit Preiss' P00750752 ex Hb

Drake; 'No. 382. Frutex, 3–5 pedalis pulcherrimus In solo calcario lateris montis 'Eliza Mountain' Perianth rubridum Floret Martii Sep 39' [Preiss script] TCD 0017877.

Possible isolectotype: 'G. preissii nob. C.F. Meisner' GH 589431.

Grevillea splendens Hortulorum ex de Noter, *Revue Horticole* n.s. Vol. 9: 33 (1909), as 'Thelemanniana, var.) Hort. '(Syn. Preissii, Meissn.)', *nom. illeg.*

Seedlings not seen. Lignotuberous, seed-facultative, variable, multi-stemmed shrubs, 0.2–0.7(–1.5) m high, 1.0–1.5 m wide with branches ascending or spreading; *branchlets* 0.8–1.2 mm wide, terete to angular, densely to moderately densely tomentose to tomentose-villous, sometimes sparsely sericeous, often glabrous-ribbed. *New growth* glabrous or with scattered appressed hairs. *Adult leaves* divided, 2.5–5.2 cm long, 10–20 mm wide, ascending to spreading, light green to dark green, glabrous rarely a few scattered appressed hairs, bi-to tripartite or pinnatipartite, always some leaves with secondary or tertiary bi- or tripartite division of proximal lobes, imparipinnate, secund, petiolate; *primary leaf lobes* 3–8; *basal rachis node* 9–20 mm long, linear; *ultimate lobes* (3–)10–27 mm long, (0.5–)0.7–0.9 mm wide; *lobe apices* acute, scarcely mucronate; *terminal lob*e often shorter than subtending lobes, simple to tripartite; *adaxial surface* smooth, sometimes obscurely punctate, the venation obscure; *margins* smoothly and tightly revolute, enclosing the abaxial surface except the midvein; *abaxial surface* bisulcate, the sulcae 0.01–0.02 mm wide, glabrous or sometimes lined with sericeous hairs, the midvein of lobes prominent; *texture* coriaceous; *petioles* 3–5 mm long. *Conflorescences* mostly subterminal or axillary in the upper axils, simple, rarely 1-branched at base; *buds* ellipsoid to cylindrical, densely villous, pedunculate; *simple inflorescences* decurved, acropetal, dense, secund; *peduncles c.* 4 mm long, decurved, sparsely to densely sericeous-tomentose; *rachis* (12–)20–40 mm long, 0.5–0.8 mm wide, sparsely to densely sericeous or the hairs sometimes crinkled and slightly spreading, straight or curved, the apex with a wavy caudate extension *c.* 1 mm long; *involucral bract* solitary, *c.* 1.5 mm long, linear; *common bracts* 0.5 mm long 0.2 mm wide, elliptic, incurved, tomentose on the abaxial surface, glabrous adaxially, early caducous. *Pedicels* 2.5–4 mm long, sparsely to densely sericeous; *torus c.* 1 mm wide, transverse; nectary conspicuous, cushion-like to slightly U-shaped, rising 0.3–0.6 mm above the torus, the margin 0.3 mm thick; *pistils* (19–)21–25 mm long; *gynophore* 2.5–4.2 mm long; *ovary* lateral, prominent, triangular; *style* 0.3 mm wide, pinkish-red, glabrous; *pollen-presenter* 1 mm long, 0.7 mm wide, yellow to green; *perianth* 5–5.5 mm long 1.0–1.5 mm wide at base, pinkish red, linear-oblong, slightly narrowed below the revolute limb; abaxial surface sparsely to moderately densely sericeous; adaxial surface glabrous at base for *c.* 1.5 mm, then curly tomentose to just below the curve, condensed about half-way along, glabrous elsewhere except along the tepal margins; perianth limb obtuse, declined to revolute, sparsely to densely sericeous. *Fruits* 12 mm long, 4 mm wide, trianguloid-acuminoid with truncate or slightly retrorse base, prominently ridged sub-basally; exocarp glabrous, rugose; mesocarp crustaceous; endocarp smooth; fructual style persistent, fragile; pericarp thin-walled. *Seeds* not seen. (Fig. 4)

Diagnostic characters: Lignotuberous, spreading shrub; foliar indumentum tomentose to tomentose-villous; branchlets angular; new growth glabrous or with scattered appressed hairs; leaves 2.5–5.2 cm long, glabrous, pinnatisect to bipinnatisect, always some with secondary division, mostly with 4–10 primary lobes, the under-surface enclosed by margins, bisulcate; leaf base 9–10 mm long; conflorescences decurved, simple to 1-branched, secund, acropetal; rachises densely brown-silky to silky-tomentose; *pedicels* 2.5–4 mm long, sericeous; perianths sparsely to densely sericeous outside below the limb, densely so on the limb; pistils 21–25 mm long, glabrous; gynophore incurved, compressed; ovary subtriangular, truncate at base; pollen-presenter 1 mm x 0.7 mm, oblique; fruits trianguloid-acuminoid, rugose, the base truncate with prominent sub-basal ridge.

Distribution: Western Australia, between Lancelin in the north to Yalgorup in the south. It occurs in the Northern Jarrah Forest and Perth IBRA Subregions of the Jarrah Forest and Swan Coastal Plain IBRA Regions, involving a number of LGAs.

Phenology: Flowers from late winter to spring. Fruits appear from late spring.

Habitat and ecology: Grows in coastal and subcoastal calcareous brown, yellow or light grey sand over Tamala limestone with *Agonis flexuosa, Eucalyptus decipiens, Hibbertia hypericoides, Banksia sessilis, Banksia* spp. Also recorded on Quindalup yellow-sand dunes with *Acacia cyclops, Olearia axillaris, Scaevola crassifolia* and *Rhagodia baccata*.

Conservation status: *Grevillea preissii* is conserved in several reserves and is not considered to be presently endangered. However, much of its habitat is under pressure from urbanisation and it should be monitored regularly. The long-lived nature of the species also enables it to persist in small, disturbed sites, without any obvious recruitment.

Fig. 4. *Grevillea preissii*. A, B. Habit and habitat (Bold Park, Perth). C. Flowering branchlets (Kings Park, Perth). D. Fruit (Kings Park, Perth). Photos: A, C, D: R.Barrett; B: P.Olde.

Etymology: The epithet honours Johann August Ludwig Preiss (1811–1883) whose large, well-documented specimen collection in Western Australia between December 1838–1842 formed the basis for the names of over 2400 Australian species. McGillivray (1975: 1–18) has given an account of his stay in Western Australia. Haebich (2020) has provided updated information.

Variation: Collections from the south of the range have a sparser perianth and pedicel indumentum.

Olde & Marriott (1995b: 109) recognised a 'Prostrate green-leaf form' and a 'Superior form'. These horticultural forms are here considered to be part of the natural variation. Morphological forms linked to distribution could not be identified during this study.

Discussion: Following this review, *G. preissii* is treated as having no subspecies. The locality of the collection *C.A. Gardner 759* (PERTH01433334) may be incorrect as Cannington is not otherwise a recorded locality for this species, though there is another record from nearby Forrestfield. All other collections are from locations much closer to the coast. A collection from Brixton Street Wetlands, Kenwick, *K.L. Brown KLB652, K. Thiele & G. Paczkowska*, 1 Jun 2007 (PERTH07810024) which has a glabrous inflorescence rachis and glabrous flowers, is *G. glabrilimba*. This and other similar plants were planted in error (as *G. thelemanniana)* and have been removed because of the potential for hybridization with the local rare endemic *G. thelemanniana* (Keighery *et al*. 2019).

Specimens seen: Western Australia: Forrestfield, *R. Aitken s.n.*, Aug 1962 (PERTH 01433377); Cottesloe, *C. Andrews s.n.*, Jun 1902 (PERTH 01938878); 900 m NW of the intersection of Mulga Rd and Gordon Rd, Stakehill, *P.G. Armstrong s.n.*, 4 Nov 1998 (PERTH 05944716); Yanchep, 25 miles [40 km] NNE of Perth, *A.C. Beauglehole* 12372, 29 Aug 1968 (NSW 100647, NSW 269104); Peppermint Grove, *K. Bennewith s.n.*, Sep 1966 (PERTH 01845403); City Beach, *K. Bennewith s.n.*, Sep 1966 (PERTH 01845381); Wanneroo Rd., near Lake Neerabup, *V. Clarke VC16*, 24 Apr 2001 (PERTH 07400152); 36 km N of Yanchep on Lancelin Rd, *M.L. Clark* 196, 10 Sep 1975 (NSW 620556); Cottesloe, *J. Burton Cleland s.n.*, 30 Aug 1908 (NSW 92117); Neerabup National Park, *D. Clyne s.n.*, Sep 1969 (NSW 127175); 7 km NE Lancelin, *R.J. Cranfield 9915*, 8 Aug 1995 (PERTH 04368711); Coogee, *R. Cranfield* 11376, 2 Jul 1997 (PERTH 04917316); Ocean Reef,

R. Cranfield 641/78, 30 May 1978 (NSW 620560, PERTH 01447874); North Guilderton, *R. Davis RD832*, 21 May 1996 (PERTH 04476794); Cottesloe Beach, *Diels & Pritzel*, Jun 1901 (PERTH 01938843); Swan River, *J. Drummond s.n.*, 1839 (CGE 13218 ex Hb. Lemann - specimen at right); Swan River, *J. Drummond* 637, *s.d.* (P 02372425); Fremantle, *A.J. Eames s.n.* & *A.J. Hotchkiss*, 23 Aug 1953 (NSW 92110); 31 miles [49.6 km] N of Bunbury on coast rd, *A.R. Fairall 895,* 21 Oct 1962 (PERTH 01938800); Cottesloe, *W.V. Fitzgerald s.n.*, Aug 1899 (NSW92118, PERTH 01938762); Claremont, *W.V. Fitzgerald s.n.*, Aug. 1901 (NSW92121); Tim's Thicket Reserve, *P. Foreman & J. Kelly TT127*, 20 Jun 2002 (PERTH 06388361); Treasure Block State Forest (proposed extension of Yalgorup National Park), *P. Foreman & G. Smith* TB534, 15 May 2008 (PERTH 07932251); Spearwood, *C.A. Gardner 747*, 15 Sep 1920 (PERTH01938819); [?]Cannington, *C.A. Gardner 759*, Oct 1923 (PERTH 01433334); Coogee, Beach, Spearwood, *C.A. Gardner 247*, 15 Sep 1920 (PERTH 01433342); East of Medina, *A.S. George* 21, 12 Jul 1959 (NSW 82897); Cottesloe, *L. Glauert s.n.*, Sep 1922 (PERTH 01938657); Floreat Park, *J.W. Green 343*, 29 May 1955 (PERTH 01938673); Yanchep National Park, E of Loch McNess, near Wanneroo Rd., *W. Greuter 22235*, 26 Sep 1991 (PERTH 03214591); Spearwood, *Dr Grieve*, Apr 1955 (PERTH 01845489); Cottesloe, *A.G. Hamilton 75*, 1902 (NSW92114); Serpentine, *A.G. Hamilton 474*, 17 Oct 1902 (NSW 92119); Between Perth and K.G. Sound, *W.H. Harvey* 709, April–July 1854 (P 02370769 ex Hb. Drake); W of Lake Joondalup, Wanneroo, *J. Havel s.n.*, 28 Jul 1965 (PERTH 04235487); Cottesloe, *R. Helms s.n.,* Aug 1895 (NSW 92113); Mouth of Swan River, *R.H[elms]*, 14 Aug 1897 (NSW 92111, PERTH 01938770); Near Fremantle, *R.H[elms]*, 14 Aug 1897 (PERTH 01845527); Fremantle, *R.H[elms]*, May 1897 (PERTH 01938827; PERTH 01845535); Plympton [?=Hillarys], *R. Helms* 41, 5 Sep 1899 (NSW 92120); NW of lighthouse at Guilderton, *M. Hislop 1064*, 21 Jun 1998 (PERTH 05390524); Yanchep National Park, *A.M. James 82*, 17 Oct 1963 (PERTH 01938711); 1 km E of Yalgorup, 32°50'10"S 115 3938"E, *E.D. Kabay* 1544, 13 Jul 1995 (PERTH 04384156); Lot 4 Mandurah Rd., Singleton, *B. Keighery s.n.*, 30 Jun 1999 (PERTH 05437601); Cockburn Sound beside Fremantle–Rockingham Rd, *K.F. Kenneally s.n.*, 13 Jul 1969 (PERTH 01845470); Off Ocean Rd., Florida, *M.R. Love 28*, 21 Jul 2000 (PERTH 05917247); Cottesloe, *A.H.S. Lucas s.n.*, Sep 1928 (NSW 92116); Swan River, *J. Mangles R.N. s.n.,* [1831] (CGE 13308, CGE 13318 ex Hb. Lindley); 32 mile peg [*c.* 51 km S of Perth on road to Mandurah], Mandurah Rd., *c.* 51 km S of Perth on the road to Mandurah, *N.G. Marchant 1*, 24 Jun 1956 (PERTH 01938754); Cottesloe, near mouth Swan River, *A. Morrison s.n.*, 4 Jul 1901 (PERTH 01938649); 70 km N of Bunbury on Highway 1, 3.7 km N of Tuart Grove Ave, *P.M. Olde 86/1001,* 30 Oct 1986 (NSW); Military Rd., *c.* 1 km from Indian Ocean Dr., north-east of Yanchep, *P.M. Olde 15/170 & I. Evans,* 7 Sep 2015 (CANB, NSW, NY, PERTH)*;* Meadow Springs Golf Course, Glendale St, Mandurah, *P.M. Olde 15/183 & I Evans*, 10 Sep 2015 (NSW 1001676); Old Coast Highway, cnr Old Bunbury Rd, Lake Clifton, *P.M. Olde* 15/185 *& I. Evans*, 10 Sep 2015 (NSW 1001678); Reabold Hill, Bold Park, City Beach, *P.M. Olde* 15/296, 22 Sep 2015 (AD, MEL, NSW, PERTH); Between Lake Clifton and Lake Preston, Yalgorup National Park, *S. Paust 1355,* 20 Oct *1972 (PERTH 01938835);* Kings Park, *H. Pearce s.n.,* Jul 1941 (PERTH 01845551); 36 miles N of Bunbury, *M.E. Phillips s.n.*, 21 Oct 1962 (CANB 005342, NSW 130180); Star Swamp Bushland Reserve, North Beach, *J. Pigott s.n.*, 29 Aug 1987 (PERTH 05940915); 1 km N of Kwinana turnoff on road to Mandurah, *J.M. Powell 2096*, 7 Nov 1985 (NSW 202536, PERTH 01845578); District Swan: in collibus calcareis prope mare, *E. Pritzel s.n.*, Jun 1901 (NSW 92122); Hadrell Rd, Yanchep, *J. Pryde, M. Morley, V. English, L. Sage s.n.*, 5 Sep 2005 (PERTH 07404859); *c.* 10 km from Two Rocks, *K. Richardson KCR63*, 27 Jun 2002 (PERTH 06145027); Mandurah, *W. Rogerson s.n.,* May 1961 (PERTH 01938746); 1 mile [1.6 km] N of Mandurah, *H. Salasoo* 4031, 20 Sep 1970 (NSW 120112); Waneroo to Yanchep, *c.* 8 miles [12.8 km] from Wanneroo, *H. Salasoo* 4172, 24 Sep 1970 (NSW 120121); Kings Park, *F.M.C. Schock 349*, 27 Jun 1918 (PERTH 01938789; PERTH 01938665); Perth, *J. Sheath s.n.*, Sep 1910 (NSW 92112); Yanchep area, *F.G. Smith 1810*, 17 Jun 1965 (PERTH 01938703); North Cottesloe, *M. Solomon s.n.*, undated (PERTH 01845497); Naval Base, *N.H. Speck s.n.*, Oct 1950 (PERTH 01845500); *c.* 10 km south-east of Lancelin on tracks east off coastal highway. *R. Spjut 724 & R. Phillips*, 26 Sep 1981 (PERTH 01845543); Smoke Tree Hill in state forest just N.E. of Yanchep NP, 57 km N of Perth, *R. Spjut 12333 & R. Smith*, 7 Sep 1992 (PERTH 04613201); 4 km S of Leach Highway at Fremantle, along Cockburn Rd, *R. Spujt 7013 & C. Edson*, 5 Sep 1981 (PERTH 01845519); 1 km E of Burns Beach, *A. Strid* 20288, 11 Sep 1982 (NSW 620557); Coronation Rd., Waroona, *D. Stewart BNC 1241*, 30 Aug 2004 (PERTH 07751494); 23.5 miles [37.6 km] S of Mandurah on Coast Rd., *M. Tindale* 3918, 1 Oct 1973 (NSW 620559); Extension of Camden Way between Railway and Pebble Beach Boulevard, Meadow Springs, Mandurah, *J. Wajon 1662*, 7 Jul 2008 (PERTH 08184518); *c.* 7 miles [12.8 km] NW of Gingin on Gingin–Eneabba Rd., *G.L. Webster* 18515, 14 Sep 1973 (NSW 620558); Walking trail on Martin's Tank Lake, *A. Worz* 044.10.20.05, 20 Oct 1994 (PERTH 04451732); 30 miles [48 km] from Perth towards Yanchep, *J.W. Wrigley s.n.*, 5 Oct 1968 (NSW 131980).

4. *Grevillea glabrilimba* (Olde & Marriott) Olde, **comb. et stat. nov.**

Basionym: Grevillea preissii subsp. *glabrilimba* Olde & Marriott, *The Grevillea Book* 1: 182 (1994).

Type: 26.1 km W of Brand Highway on road to Greenhead, Western Australia, *P.M. Olde 91/89,* 14 Sep 1991 (holo: NSW362991; iso: NSW298991; PERTH04700201).

Grevillea 'Seaspray' Hort., *Grevillea* 'Gilt Dragon' Hort., *Grevillea* 'Soft Touch' Hort., *Grevillea* 'Magic Lantern' Hort.

Seedlings not seen. *Mature plants* lignotuberous, seed facultative, spreading to dome-shaped, multi-stemmed, grey-green to dark green shrub, 0.2–0.5(–0.7) m high, 1.0–1.5 m wide with branches spreading from base; *branchlets* 0.9–1.2 mm wide, angular, densely white-villous or tomentose-villous, with green striation decurrent from leaf bases, often decurved at the tip. *New growth* coppery green soon grey-green, openly subvillous. *Adult leaves* divided, 1.5–2.5 cm long, 5–10 mm wide, ascending to spreading, green or grey-green, openly villous, usually bipinnatisect, some primary lobes simple or rarely some lobes with tertiary bi- or tripartite division, imparipinnate, secund, shortly petiolate; *primary leaf lobes* 4–8; *basal rachis node* 4–12 mm long, linear; *ultimate lobes* 2–13(–15) mm long, 0.8–1 mm wide, linear, the *terminal lobe* usually shorter than subtending lateral lobes; *lobe apices* obtuse-mucronate, the mucro c. 0.2 mm long, recurved with a reddish-brown terminal spine 0.1–0.2 mm long, non-pungent; *adaxial surface* openly villous to glabrous, smooth, not punctate, the venation obscure; *margins* smoothly revolute, fully enclosing the under-face almost to the midvein; *abaxial surface* enclosed, bisulcate, the sulcae *c*. 0.1 mm wide, densely white-sericeous, the midvein prominent, *c*. level with margin, with scattered long, wavy, pilose hairs; *texture* softly coriaceous; *petioles* 0.5–2 mm long, villous. *Conflorescence* decurved, terminal or subterminal on side branches, simple, secund to subcylindrical, acropetal, pedunculate; *buds* narrow-cylindrical; *peduncles* 5–10 mm long, decurved, sparsely to moderately densely sericeous-tomentose; *rachises* (7–)23–30(–40) mm long, 0.8 mm wide, straight or slightly incurved, glabrous or with a few scattered spreading hairs, sometimes openly tomentose at base; *rachis extension* 0.7 mm long, linear, erect or incurved distally, glabrous or with a few spreading scattered hairs; *involucral and peduncular bracts c*. 5 mm long, 0.5 mm wide; *common bracts* 1.5 mm long 0.5 mm wide, ovate-acuminate, sparsely villous, the apex densely villous on the abaxial surface, glabrous adaxially, early caducous. *Pedicels* 3–4 mm long, 0.25 wide, glabrous; *torus* 0.8 mm wide, oblique at *c*. 10°; tepals attached to the outer rim of the torus; *nectary* conspicuous, cushion-like to slightly U-shaped, rising 0.5–0.6 mm above the torus, the margin 0.3 mm thick, entire; *pistils* 21–25 mm long; *gynophore* 3–4 mm long; *ovary* 1.3 mm long, lateral, prominent, triangular, the base truncate to retrorse; *style* 0.3 mm wide, pink-red, glabrous, gently incurved; *style*-end green to yellow; *pollen-presenter* 1.2–2 mm long, 0.7–1 mm wide, yellow, oblong-elliptic, lateral to oblique at *c*. 70°, the surface convex with raised stigma; *stigma* distally off-centre; *perianth* 5.5–7 mm long, 1.5–1.8 mm wide at base, red, pinkish red or orange-red, deciduous, falling as an entire unit, tepals coherent except along the dorsal suture, the tubular section narrowly ventricose, tapering below the revolute limb; *abaxial surface* glabrous; *adaxial surface* glabrous at base for *c*. 1.5 mm, villous above adjacent to the ovary, the hairs usually shorter towards the curve, the hairs not condensed into a beard, glabrous distally except along the tepal margins; *perianth limb* spheroidal with depressed apex revolute, glabrous. *Fruits* 12–15 mm long 4–6 mm maximum width, follicular, trianguloid-acuminoid with base transversely or obliquely truncate, prominently ridged; fruiting style persistent, fragile; exocarp rugose, shiny, non-viscid; pericarp thin-walled, crustaceous. *Seeds* not seen. (Fig. 5)

Summary of diagnostic characters: Lignotuberous, spreading shrub; foliar and cauline indumentum loosely villous or tomentose-villous; branchlets angular; new growth openly subvillous; leaves 1.5–2.5 cm long, secund, bipinnatisect with 2–3(–4) paired primary lobes, the primary lobes occasionally simple or with frequent tertiary division; ultimate lobes 0.8–1 mm wide, narrow-linear; margin smoothly revolute, fully enclosing the under-surface; adaxial surface with obscure venation; abaxial surface bisulcate with, two very narrow, sericeous sulcae, the midvein prominent; basal rachis node 4–10 mm long; simple leaves absent; conflorescences acropetal, decurved, subcylindrical to subsecund, subterminal or terminal; peduncles densely hairy; rachises 23–30(–40) mm long, glabrous or a few isolated, spreading hairs scattered; common bracts 1.5–5 mm long, 0.5 mm wide, caducous; pedicels 3.5–4 mm long, glabrous; pistils 21–25 mm long, glabrous; pollen-presenter 1.2 mm long, 0.7 mm wide; pedicels and perianth including the limb glabrous.

Distribution: Western Australia, in near-coastal areas west of the Brand Highway between Leeman in the north and Cervantes in the south, with the majority of specimens collected near Jurien Bay.

Phenology: Herbarium records indicate scattered flowers in autumn but the main flowering is from late July to September.

Habitat and ecology: Grows in shallow calcareous sand or crevices in limestone capstone.

Conservation status: Not presently endangered.

Etymology: Latin *glaber*, and *limbus*, a reference to the glabrous perianth limb of this species.

Fig. 5. *Grevillea glabrilimba*, flowering branchlets (Coorow-Greenhead Road). Photo: P. Olde.

Variation: Most specimens have grey foliage but a number, notably *P.M. Olde* 15/177 *& I. Evans* from Canover Rd, Jurien have green leaves. Whether this is indicative of some further variation warranting taxonomic recognition is presently under study, along with the 'Fine-leaf form' *sensu* Olde & Marriott (1995b: 110). The holotype and other specimens have glabrous inflorescence rachises whereas the isotype at NSW has a few scattered spreading hairs.

Discussion: Hevroy (2016) reported that *G.* [*preissii* subsp.] *glabrilimba* did not share a cpDNA haplotype with *G. preissii* subsp. *preissii* which suggests that they are not closely related. From four plants sampled, two haplotypes were found for *G. glabrilimba,* which alone invites further analysis and study of that taxon (see discussion above under Variation). However, the two haplotypes were resolved as sister in the nDNA microsatellite Neighbour Joining Tree and together were resolved as sister to *G. preissii*. This does not necessarily support their recognition as the same species because *G. gillingarra* and *G. exposita* were also resolved as sister in the same tree.

Grevillea glabrilimba is here distinguished from *G. preissii* at specific rank on phenetic grounds. *Grevillea preissii* differs in its generally longer basal rachis nodes, its flowers bearing hairs on the outer surface of the perianth both below and more densely on the limb, and by its usually densely tomentose inflorescence rachises and sparsely hairy pedicels. *Grevillea glabrilimba* is sometimes confounded with *G. delta* (McGill.) Olde and Marriott. *Grevillea delta* has sessile leaves with a short basal rachis node (3–4 mm long), generally longer ultimate leaf lobes, and shorter, conspicuously hairy rachises. The branchlet indumentum is sometimes similar to *G. glabrilimba* but *G. delta* has long hairs up to 2 mm long usually scattered throughout. Both have a glabrous abaxial perianth surface, but plants with perianths bearing scattered hairs are also presently accommodated in the circumscription of *G. delta*.

Specimens seen: Western Australia: 10.5 km ENE of Jurien, *B.G. Briggs* 6333, 26 Sep 1976 (NSW 605178, PERTH); Road to Jurien Bay, *D. Clyne* 124, Sep 1969 (NSW 605180, PERTH); 17.9 km SSE of Leeman towards Coorow, *R. Coveny 7996 & B.R. Maslin*, 2 Sep 1976 (K, NSW 605169, PERTH); 13 km from Green Head towards Brand Highway (9.2 km from turnoff, *J. McCarthy 16, D. Bedford, J. Everett, B. Slade*, 2 Nov 1985 (K, NSW 202630, PERTH); 3.5 km E of Jurien, *D.J. McGillivray 3290 & A.S. George*, 11 Jun 1976 (NSW 605173); 3.5 km E of Jurien, *D.J. McGillivray 3291 & A.S. George*, 11 Jun 1976 (NSW 605176); 3.5 km E of Jurien, *D.J. McGillivray 3292 & A.S. George*, 11 Jun 1976 (NSW 605177); 32 km from Halfway Mill Roadhouse, *P.M. Olde* 86/966, 26 Oct 1986 (NSW 908418); 29.3 km W of Halfway Mill Roadhouse, *P.M. Olde* 91/90, 14 Sep 1991

(NSW 534723, PERTH); 31.1 km from Halfway Mill Roadhouse, *P.M. Olde* 91/92, 15 Sep 1991 (NSW 363122); Canover Rd, Jurien, near corner Emma Rd, *P.M. Olde* 15/177 *& I. Evans*, 7 Sep 2015 (AD; NSW; PERTH); Corner Premier and Zendora Sts, Jurien Bay, *P.M. Olde* 17/34 *& K. Alcock,* 3 Sep 2017 *(*CANB, NSW, PERTH); Coorow-Greenhead Rd, 11 km west of Brand Highway, *P.M. Olde* 17/38 *& K. Alcock,* 3 Sep 2017 *(*CANB, MEL, NSW, PERTH *distribuendi*); Near Green Head, *M.E. Phillips s.n.*, 24 Sep 1962 (CANB 012380, NSW130179); 3 miles [4.8 km) east of Jurien Bay, *R.V. Smith* 66/171, 1 Sep 1966 (MEL, NSW 605167); Quarry, E of Jurien, *C. Woolcock G35 & D. Woolcock*, 16 Aug 1985 (NSW534722); alongside Indian Ocean Drive, *c.* 4.5 km south of Jurien Bay, *D.A. Young* Waherb 16_012, 8 Jul 2016 (NSW 1002526).

5. *Grevillea bundera* (Keighery) Olde and Keighery, **comb. nov.**

Basionym: *Grevillea variifolia* subsp. *bundera* Keighery, *Nuytsia* 12: 294 (1998).

Hakea bundera (Keighery) Christenh. & Byng, *Global Flora* 4: 78 (2018).

Type: 15.6 km N of Coral Bay turnoff on Exmouth Road, Western Australia, *G.J. Keighery & N. Gibson 323*, 25 Aug 1992 (holo: PERTH 04055217).

Diagnosis: Apparently related to *Grevillea variifolia*, but differing in its hard leaves with triangular, pungent lobes.

Seedlings not seen. *Mature plants* apparently seed-obligate, compact, dome-shaped, grey to grey-green *shrub* 0.3–1.6 m high, 0.3–2 m wide with spreading to ascending branches. *Branchlets* 0.6–0.9 mm wide, angular, subsericeous. *New growth* silvery-grey. *Adult leaves* simple and divided, 1.1–3 cm long; *simple leaves* 2.3–4 mm wide, obovate to elliptic, occasional; *divided leaves* 5–25 mm wide, flat to undulate, obovate to subcruciform, bifid to pinnatifid, usually with broad-triangular lobes, including one terminating the primary leaf rachis; *primary leaf lobes* (2–)3–7; *leaf lobes* 2–3(–6.2) mm long, 1.75–3.5 mm wide at base, triangular, spinose; spines 1.5–2.5 mm long, straight, pungent; *apices of leaf lobes* acute; *basal rachis node* not applicable; *leaf-base* cuneate; *margins* recurved to revolute; *adaxial surface* smooth, glabrous or almost so, the midvein, primary, secondary and tertiary lateral veins, intramarginal veins and reticulum prominently raised and discolorous; *abaxial surface* exposed, densely sericeous, the midvein and lateral veins evident similarly hair-covered; *texture* coriaceous; *petioles* c. 2 mm long. *Conflorescence* simple, erect on descendent rachises, ±secund, 12–30-flowered, acropetal to subsynchronous, pedunculate; buds not seen; *peduncles* 5–25 mm long, straight, subsericeous; *rachises* 15–25 mm long, ±densely subsericeous; *common bracts* not seen, caducous. *Pedicels* 2.5–3 mm long, openly sericeous; *torus* 0.8–1.2 mm wide, slightly oblique; *nectary* rising *c.* 0.5 mm above the torus, conspicuous, fleshy, lunate with thick walls; *pistil* (18–) 25–28 mm long, glabrous; *ovary* obliquely ovoid, the base truncate; *gynophore* 2.5–4 mm long; *style* red, gently incurved; *pollen-presenter* 0.9–1.5 mm long, 0.8–1.2 mm wide, yellow, oblique; *perianth* 6 mm long, 1.25 mm wide, pinkish red, narrow-ovoid, with sprinkled appressed hairs outside below the curve, subsericeous on the pink limb, densely pubescent inside, the hairs aggregated into a beard. *Follicles* 12–16 mm long, 6.5–7 mm wide, ovoid-ellipsoidal; *pericarp* 0.3–0.4 mm thick at the suture. *Seeds* not seen. (Fig. 6)

Distribution: Western Australia. It occurs in the Cape Range–Wooramel Subregions of the Carnarvon IBRA Region in the Carnarvon and Exmouth LGAs, roughly between Cape Cuvier (near S end of Lake McLeod) and Rough Ra. (inland from Ningaloo).

Habitat and ecology: Grows in open scrub on Quaternary calcarenites and Pleistocene limestones with red sand. Associated species often include *Triodia basedowii*, *Grevillea stenobotrya, Hakea stenophylla, Scaevola tomentosa, Acacia tetragonophylla, A. coriacea.*

Phenology: Flowers mainly in winter–spring, but abundance is often dependent more on rainfall than seasonality.

Conservation status: According to the Western Australian herbarium this species is not of conservation concern.

Etymology: Named after the Quaternary Bundera calcarenites on which this taxon is a common and distinctive component of the shrub flora (Keighery *et al.*1998).

Discussion: Mature leaves of *G. variifolia,* in which species *G. bundera* was previously included as subspecies, are obovate-cuneate and generally longer (17–) 25–43 mm long), apically dentate or deeply triangular-lobed, and with petioles 3–6 mm long. Among the specimens of *G. variifolia* examined, a greater proportion of simple leaves was observed than for *G. bundera*. The conflorescences of *G. variifolia* also tended to be longer (rachises up to 50 mm long) and regularly 1-branched. Although the two species are surely close-related, they occur in consistent, fully diagnosable populations in different habitats informed by underlying geology. We therefore recognise them both as deserving recognition as co-equal species. Both species have been examined in the field.

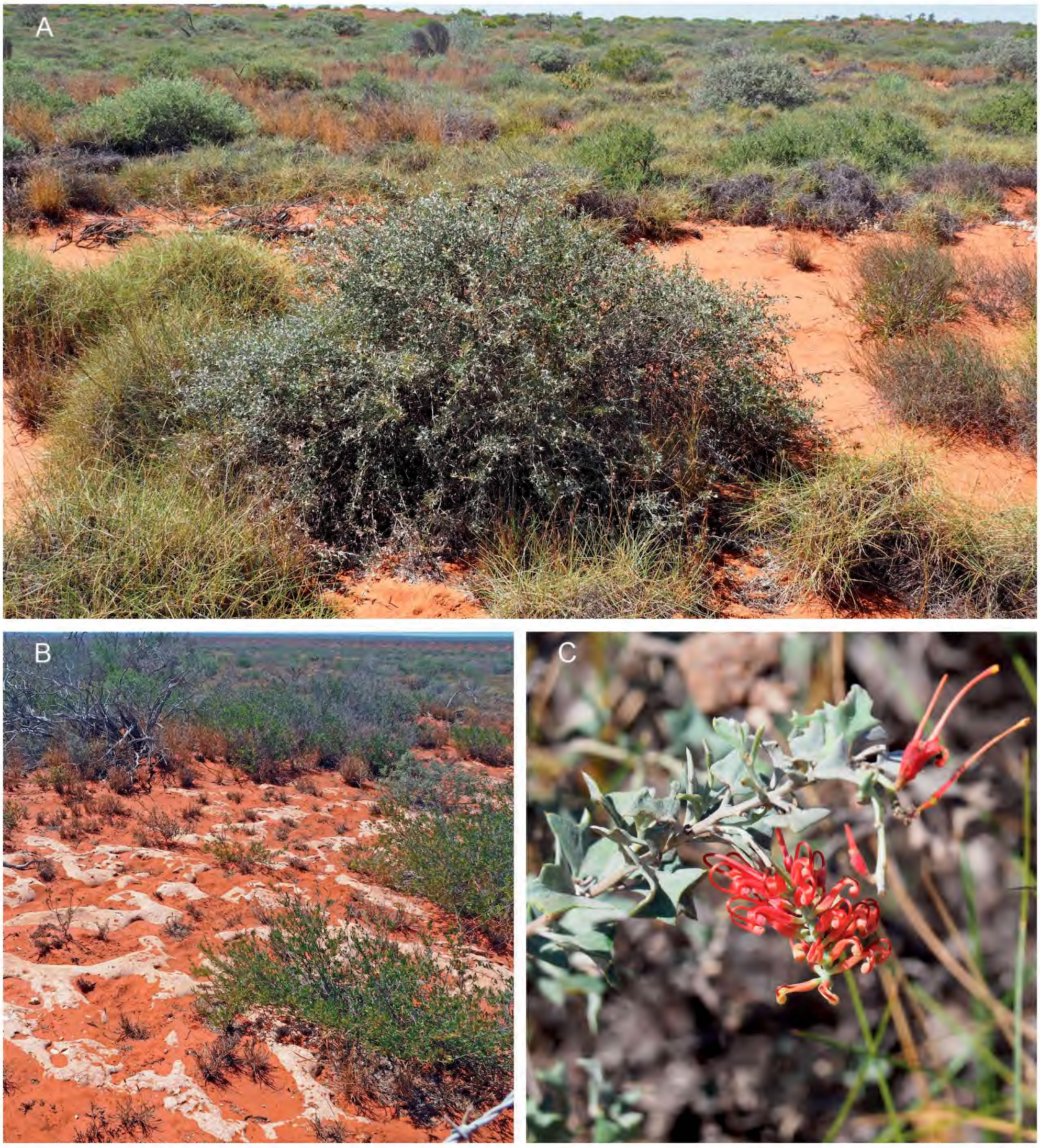

Fig. 6. *Grevillea bundera*, Exmouth Rd, Coral Bay. A, B. Habit and habitat. C. Flowering branchlet. Photos P. Olde.

Hevroy (2016) found that two sampled populations of *G. bundera* had two unique haplotypes, worthy of further investigation for the existence of a possible cryptic species. She also reported evidence of hybridism between *G. variifolia* and *G. bundera* in one sample. The existence of such a plant can be explained by the close-relatedness and geographic proximity of the two species and does not undermine, in our view, the change of classification proposed here.

Specimens seen: Western Australia: 127.1 km S of Learmouth, *A.S.George 2402* (CANB (*n.v.*), NSW 462963, PERTH (*n.v.*)); Exmouth Rd, Coral Bay, 58.5 km from turn-off at NW Coastal Highway, *P.M. Olde* 19/55 *& I. Evans,* 13 Sep 2019 (NSW, PERTH).

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Validation of *Riccardia pseudodendroceros* R.M.Schust. ex M.A.M.Renner (Aneuraceae: Marchantiophyta)

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Abstract

The name *Riccardia pseudodendroceros* Schust. ex M.A.M.Renner (Aneuraceae: Marchantiophyta) is validated.

Introduction

Schuster provided a Latin diagnosis of *Riccardia* subg. *Dendroceropsis* (1985: 452) and stated that the sole species included in the new subgenus was "*Riccardia pseudodendroceros* Schust., *sp. n.*" Under the intended new species name he cited details for a specimen selected to serve as the type and further stated that "The above diagnosis [i.e., that provided for *R.* subg. *Dendroceropsis*] represents a descriptio generico-specifica". Under the *International Code of Nomenclature for algae, fungi and plants* (Turland *et al.* 2018; hereafter "ICN") provision of a single description or diagnosis to simultaneously validly publish the names of both a genus and a species (*descriptio generico-specifica*; ICN Art. 38.5) is an exception to the requirements for every name of a new taxon to be accompanied by a description or diagnosis (ICN Art. 38.1). However, the exception only applies to names at the specified taxonomic ranks. Schuster's simultaneously diagnosed taxa were of subgeneric and specific rank and are thus not covered by the exception. Therefore, the diagnosis provided by Schuster (1985) can be regarded as validating the name of his new subgenus, *Riccardia* subg. *Dendroceropsis* (Schuster 1985: 452), but leaving his intended new species name, "*Riccardia pseudodendroceros*", as a *nomen nudum* and not validly published.

"*Riccardia pseudodendroceros*" was subsequently provided with an English description and illustrated by Brown and Braggins (1989: 99, Fig. 27), who examined and illustrated a fragment of the type material sent to them by Schuster for study (E.A. Brown *pers. comm.*; Brown and Braggins 1989: 99). The fragment examined by Brown was presumably returned to Schuster, as it is not in AK (Ewen Cameron, AK *pers comm.*). Schuster's type, along with the rest of his personal herbarium, has been incorporated into the Field Museum of Natural History (F). However, no Latin description or diagnosis was provided (ICN Art. 39.1) presumably because they believed Schuster's name to have been validly published in 1985. Schuster's name was therefore not validated when the taxon was treated by Brown and Braggins (1989). Nor was it validated by Söderström *et al.* (2016), who also refer to the Schuster's invalid publication, as no description or diagnosis in Latin or English was provided (ICN Art. 39.2).

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Riccardia pseudodendroceros is validly published for the first time below, where details of the holotype specimen are cited and a description in English is provided. This is based on the subgeneric diagnosis provided by Schuster (1985) and on the description of *Riccardia pseudodendroceros* composed by Brown and Braggins (1989).

Nomenclature

Riccardia pseudodendroceros R.M.Schust. ex M.A.M.Renner, *sp. nov.*

Type: New Zealand, South Island, Paparoa Range, near Mt. Euclid, 4300–4400 ft, in tussock zone, *R.M. Schuster 84-1503* (holo: F, *n.v.*).

= *Riccardia pseudodendroceros* R.M.Schust., *Phytologia* 56: 452 (1985) *nom. inval.* [description or diagnosis not in Latin]

= *Riccardia pseudodendroceros* E.A.Br. & Braggins, *J. Hattori Bot. Lab*. 66: 99 (1989) *nom. inval.* [description or diagnosis not in Latin]

= *Riccardia pseudodendroceros* L.Söderstr. *et al*., *PhytoKeys* 59: 440 (2016) *nom. inval*., *nom. nud.*

Diagnosis: *Riccardia pseudodendroceros* is distinguished from all other *Riccardia* species by its combination of dorsal epidermal cells each protruding forming a low rounded mamilla, lacking chlorophyll, and smaller and sharply demarcated from the internal thallus cells; the thallus narrow, elongate and with an acute wing; lateral branches closely ramifying, with up to four orders of branching, branch thallus frequently one cell thick; margins of ultimate branches upturned, crispate, or sinuose.

For a complete description and an illustration see Brown and Braggins (1989: 99–101).

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The Parson to the Plankton: George Israel Playfair (1871–1922)

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Abstract

It is one hundred years since 'the late G.I. Playfair, Australia's foremost student of freshwater algae' died, in Tauranga, New Zealand, but the value of his collection, and descriptions of many freshwater photosynthetic organisms from New South Wales, is current and growing.

Introduction

The beginnings of freshwater phycology in Australia were patchy and disparate (Cowan & Ducker, 2007). Ronald Gunn (1808–1881) included freshwater algae among his wide-ranging collections in Tasmania for William Henry Harvey. Henry Watts (1828–1889) collected across much of Victoria, corresponded with Harvey and other European scholars, and published in the *Victorian Naturalist*. Alfred Douglas Hardy (1870–1958), who worked for the Victorian Water Board, sent his specimens to George Stephen West, and published his findings in the *Victorian Naturalist*. Thomas Lane Bancroft (1860–1933) sampled algae in parts of Queensland, looking for mosquitoes, and passed on his algal collections to F.M. Bailey (1827–1915), who sent them to Martin Möbius, Oscar Borge and Wilhelm Schmidle, and then re-published their papers in translation in the *Botany Bulletin* (Queensland Department of Agriculture).

In New South Wales, George Israel Playfair investigated freshwater organisms at Lake George, on *Moura* station near Molong, and then, while fulfilling his duties as a Non-Conformist minister, at numerous sites around Sydney, Lismore and in the Richmond River catchment.

Playfair, born in Kent in 1871 and brought up in Wakefield, West Riding, Yorkshire, was the son of a woollen mill manager. Playfair was educated at nearby Silcoates Hall and travelled to the antipodes in the early 1890s. George, and his brother Thomas, left England on the SS *Oceana* on 2nd February 1893. His occupation is given as Auctioneer. According to the curriculum vitae on the fly of one of his notebooks, Playfair landed in New South Wales on '*Fri March 23rd 1893*'. He arrived with a fascination for microscopy and very likely an inherited microscope. He worked as a tutor at *Winderradeen*, near Lake George in 1894, at *Moura*, via Molong, in 1895, and *Everimar*, near Orange in 1897. He also taught at Scots College, Bellevue Hill in 1896. From 1898 to April 1900 Playfair worked as bookkeeper for a guano mining company in the Capricorn and Bunker Group off the Queensland coast, probably living on North West Island. For more on the mining operations see Daley & Griggs (2006).

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On his return to Sydney, he looked for work, even though he appears to have had some 'private means'. The colourful Rev. Edward Tremayne Dunstan had him appointed the lay pastor at Auburn Congregational Church in August 1900, and George threw himself into the task with gusto and skill. He raised funds and completed the building of the chapel, in Queen St, diagonally opposite St John of God Roman Catholic Church (Sands Directory, 1905, p204). [The building is long gone, lost under St John's Primary School.] He joined with the other non-conformist clergy to set up a Protestant Endeavour Group for the youth. He arranged musical evenings, public prayer meetings, family picnics and much more. And while doing this he started writing papers on freshwater organisms for the Linnaean Society of New South Wales.

Playfair completed his ecclesiastical training in 1905 and was given a three-month position with a Presbyterian minister in Muswellbrook, and then returned to work at Dunstan's *Whitefield Institute*, Pitt St, until May 1907. In May that year he returned to Auburn and continued there until July1912. He was never ordained.

In 1907 Joseph Henry Maiden, the Director of the Royal Botanic Gardens, Sydney, had made him 'honorary in charge of freshwater algae' (Maiden 1913) a position he retained until 1912. His controversial paper on polymorphism in desmids (Playfair 1910) brought him some notoriety. He was awarded a Government Science Research Scholarship of the University of Sydney, in Hydrobiology and Plankton in 1913, through the Linnaean Society of NSW (*Daily Telegraph*, Thursday 27 March 1913: 12).

While his scientific fortunes were on the rise, his clerical star had faded a little. In August 1912 he moved to the northern rivers. He became a popular organist, marriage celebrant and lay preacher on the Presbyterian circuit around Lismore. He was involved in the tennis club and in fund raising for the war effort. He was given an extension of the scholarship by the University of Sydney in early 1915 (*Daily Telegraph*, Tuesday 13 April 1915: 8)and he was still publishing at that time. After finishing his research for the University of Sydney, he was appointed an assistant teacher at Murwillumbah Superior Public School in 1918 (*Northern Star*, Friday 16 August 1918: 4). Playfair did not appear to earn tertiary qualifications for his effort.

He became unwell in 1921 and went to the Bay of Plenty to stay with his brother and family to recover. Before he left for New Zealand, Playfair donated his scientific library, 111 items, to Linnean Society of New South Wales (*Proc. Linn. Soc. NSW* 46(4): 531 1921). As the Society no longer has a library, Playfair's books and journals are now scattered between the University of Sydney, the Australian Museum and the library of the Royal Botanic Gardens, Sydney. He didn't stop collecting as there is a folder of notes and a number of specimen bottles from Tauranga.

He died in Tauranga, New Zealand on 8 October 1922 (New Zealand Register of Births, Deaths and Marriages 1922/8594; *Bay of Plenty Times*, 9 October 1922: 2). Despite searches, a grave or headstone is yet to be located (Dr Phil Novis, pers. comm.).

Methods

The on-line British Census site and the New Zealand Register of Births Deaths and Marriages, the National Archive of Australia, including the Trove search engine for Newspapers and magazines, were all used, as was the Daniel Solander Library at the National Herbarium of New South Wales. By providing access to local newspapers of the period, when articles on church events made good copy, Trove provided much background on Playfair's non-scientific activities and dates for his awards. The special collections in the Daniel Solander Library included the notebooks and papers of Playfair and notes made by Valerie May when she was the Phycologist at NSW. These, along with the Journals, provided the material for a picture of Playfair the researcher.

Results

The Notebooks

There are ten notebooks. Some are records of collections, with tiny drawings, specimen dimensions and locality data (in code). Others are lists of bottles by contents and by locality. There is the one which gives a catalogue of all the bottles in the spirit collection with contents, an index to sites and an index to genera. In addition, there is a later catalogue, on lined paper folded in an envelope.

The list of books in the collection is as follows:

1. the little brown exercise book, with the 1894 pencil and water colour drawings;
2. the large Black Book, the foolscap exercise book referred to by Maiden (1913);

3. folder made from an exercise book cover marked *Cleve 1868*, loose leaves with various cross-referenced lists;
4. *Mathematics*, a red and blue exercise book from his Silcoates Hall days, used as a reference and library catalogue to 1914;
5. The small green exercise book, with plenty of collections and notes;
6. The red-edged black exercise book, an illustrated compilation of freshwater organisms from all kinds of sources…, his reference book and primer on taxa;
7. The little black book, a second bottle catalogue;
8. The book called 'list of bottled specimens' which has the lists of correspondents and who had received what, and more;
9. The very thin book, full of tracings and their sources;
10. *Future Use*, a letter writing paper pad used as a folder, with his New Zealand collection notes in it.

These were digitally imaged in 2007, and the images stored on a floppy disc. Fortunately, there has been a digital copy kept. A copy of the Catalogue is available on request from the librarian, Daniel Solander Library, Royal Botanic Gardens, Sydney.

There are also bundles of notes for almost all collecting sites, and of algal groups he wrote about. The folder covers are made from stiff brown paper, about A3 size and the better-preserved ones still have a double long stitch, to hold the contents in the folder. The notes are on both lined and unlined paper, and both sides are crammed with information about the organisms and where they were found.

Fig. 1. The Playfair spirit collection at the National Herbarium of New South Wales (NSW).

All the notebooks are interleafed with loose pieces of paper. Many of these are tracings of illustrations from major works which were not in his possession, but they also include lists of prices for Zeiss ocular pieces, lists for music for M (morning prayer) and E (evensong) for the coming month, charity receipts, and addresses

for international correspondents. There is a list of commonly encountered German adjectives and his English equivalents on the back of a letter from Gilbert Morgan Smith, the American phycologist, thanking Playfair for a reprint. Playfair comes through as very normal and familiar as a researcher.

The Bottles

He kept his samples in rubber stoppered glass vials, over 350 of them, initially in formalin. They were carefully numbered and a look at the catalogue that went with them demonstrates he saved a very substantial quantity of his field collections. Because by their very nature field collections of freshwater organisms, particularly plankton, are mixed, they are less than useable as Type specimens, but they remain Type-Site collections. As the plates for printing have long ago been misplaced, and the graphite drawings are often part of working notes, the published illustrations are considered Iconotypes when cited as such, and this has been done on few occasions. The individual bottles have not yet been incorporated in the NSW database.

If Playfair had a collection of slides they have not come down to us. There are four slides in the A.H.S. Lucas Collection (NSW), where Lucas attributes the material to Playfair's collections (see table 1). Mounted by Lucas in glycerine jelly, they are all in moderate condition.

Table 1. Slides from Playfair's collections held in the A.H.S. Lucas Collection (NSW).

Tray No.	AHSL slide no.	GIP bottle no.	Determination on slide label
37	202	23	*Oscillatoria nigroviridis* Nordsteadt, incl. *Peridinium tabulatum.* Pipehead Basin
37	203	23	*Oscillatoria nigroviridis* Nordsteadt, incl. *Peridinium tabulatum.* Pipehead Basin
53	277	29	*Oedogonium borisianum* (Le Cleve) Wittrock
68	339	102	*Botryococcus braunii*, with *Aphanothece microscopica*

Playfair had a wide collection of lenses, Watson, Beck, Leitz and Zeiss, which he had worked out ways of interchanging to achieve the levels of enlargement he required. He left details of how he did this among his notes. At least for some, we can also read from where and for how much those lenses were purchased.

The published work

George Playfair published thirteen papers in the *Proceedings of the Linnaean Society of New South Wales*, one for the *Australasian Society for the Advancement of Science* (Playfair 1911) and Supplement 1 to Maiden & Betche's *Census of New South Wales Plants* (Playfair 1917). The four earliest papers are on desmids (Playfair 1907, 1908, 1910, 1911). Seven later papers are about plankton (Playfair 1912, 1914, 1915b, 1916b, 1918, 1921, 1923). Playfair (1921) concentrated on the flagellates in the plankton and approached a monograph in form, while the three other papers are monographic treatments of certain groups (Playfair 1915a, 1916a, 1919).

Discussion

On reading Playfair's papers it becomes abundantly clear that he took much more than a philatelist's approach to his work. He is a natural historian rather than an ecologist but the descriptions of waterways with observations of catchment vegetation and soil type show a keen eye for correlations. He realised very soon after starting to collect that repeated sampling of sites gives the observer a better and better picture of what is going on.

On Desmids

Desmids are haploid unicellular or colonial plants with the cell having two mirror image half-cells, fitted with a complete set of organelles in each half and one central nucleus. They multiply by mitosis followed by the production of a full new half-cell on the other side of the isthmus, with the most recent halves back-to-back between the former halves. Sexual reproduction is by conjugation, and the resulting diploid zygospore is a resting phase.

In 1910 Playfair claimed to have spent fourteen years looking at desmids. He pointed out, (and not only for the desmids) that frequently he was constrained by the availability of certain publications in the libraries to which he had access. He cited many of the leading researchers of the day, and corresponded with them, gradually building a very creditable reference collection in several European languages.

Playfair (1907, 1908) both contain descriptions of a number of species new to science, and plenty of forms and variations. The localities cover the Goulburn area, and the Central Western Slopes as well as sites round Sydney. Playfair used the literature he had to hand and would happily acknowledge mistakes and make corrections in following papers.

Playfair (1910) includes a very large number of examples of morphological variation, across numerous genera, which he refers to as *degeneration*. He then makes the point by presenting Plate xi, as '*Docidium trabecula* (Ehr.): forms' (Playfair 1910). He drew attention to his Figure 7 in that plate, with the sequence of divisions indicated, of the result of rapid division in the taxon he described as *Docidium ehrenbergii* var. *delpontei* Playfair. He points out that the chains often fall apart during collection, but: *In hot weather, and in shallow stagnant water, however, they are quite the rule of life, and are the origin of the immense number of degenerate forms connected with a species* (Playfair 1910: 461).

Playfair (1911) contains a discussion of the extrapolations he had made from his observations of fresh and standing live collections of desmids and his very careful cross checking of published names for species, varieties, and forms in numerous genera. He felt that people were looking at the evidence incorrectly: *In other words, we have considered the Desmids in some ways too much in the light of the growth of the higher orders of plants, …their life history a continuous upward growth to a sexual maturity; whereas among the Desmidiaceae the succession of polymorphic forms, which constitutes the life history of any species, exhibits in the characteristics of the several forms a gradual degeneration from a perfect sporangial type, and the objective of desmid life is not the production of zygospores but the multiplication of cells.* (Playfair 1911: 279).

He had charts, referred to in the text but unpublished, to illustrate his arguments and extrapolations. We have not located the charts. Without the backing of controlled growth cultures his opinions remained just that. Time has supported much that he proposed: there were many fewer species than had been described.

Every Desmid species holds a certain number of distinct possibilities as regards form, length, breadth, and ornamentation, and it is the immense number and variety of the combinations that can be made out of these that is the cause of the vast bulk of the species and the intricate character of its life history – the connection, that is, of its innumerable polymorphic forms. (Playfair 1911: 296).

By modern standards Playfair's 'bottles on window-sills' were very poorly designed experiments, but his observations were still valid: as the conditions changed, the successive half-cells reflected the stresses placed on the organism; the sculpturing and even the shape were dependant on prevailing conditions. He was attempting to replicate what he observed and noted in fresh field collections. This contrasted with the 'perfect symmetry in mature specimens' idea, championed by G.S. West. That concept allowed the description of forms, varieties and even new species based on minor changes in shape or decoration…even the idea that one half-cell could be in a different taxon to the other half-cell!

In the early 20th Century neither the mechanics of cell division in desmids nor the impact of environmental conditions or rapidity of the processes were understood. As Playfair (1910) stated he had corresponded with G.S. West about his descriptions in the two earlier papers and felt it necessary to publicly defend his position as West (1909), when describing algae from Yan Yean Reservoir in Victoria, had publicly challenged his determinations.

When taking stock of Playfair (1910, 1911) it is well to remember that cell theory was in its infancy. While the existence of chromosomes and their behaviour in the phases of nuclear division had been described, the significance of the information they were carrying was yet to be widely understood. It is unlikely that either West or Playfair appreciated the role of the chromosomal crossings-over. Playfair described what he observed and argued from observation. Standing up to the Mason Professor of Botany, Birmingham, was a brave gesture.

In *The Biology of the Desmids* (1981), A.J. Brook makes passing reference to Playfair (1910). The Tasmanian phycologists P.A. Tyler and H.U. Ling cited Playfair (1907, 1908) but appear to have passed over Playfair's (1910, 1911) discussions of polymorphism in their experimentally based work (Tyler 1970; Ling & Tyler 1972, 1974, 1976). Many of their conclusions appear to support his observations.

The Plankton

Playfair (1912) demonstrates that he understood the complexity of the Sydney water supply system. The richness of the biodiversity across the numerous sites is well documented. His surprise at the dominance of the diatom *Melosira granulata* is an interesting observation. Today it is common to find white watermarks of diatoms on rocks and snags in inland rivers in New South Wales, indicating high diatom populations in the plankton of those rivers. The two papers on the planktonic organisms of the Richmond River area (Playfair 1914, 1915b), show Playfair working to compare the floristics of these two distinct river systems, and linking the differences to environmental factors.

He continued to describe new taxa, and the sixteen celled colonies of *Volvulina steinii* Playfair are first described in Playfair (1915b).

While working to complete the *Supplement to the Census* (Playfair 1917) he continued to review his collections and to correct and expand his descriptions of flagellated green algae (Playfair 1916b) and right across the range of plankton (Playfair 1918).

The monographic papers

Recent interest in Playfair's (1915a) work on the Euglenoid genus *Trachelomonas*, where the flagellated, and frequently photosynthetic protist lives inside a housing called a theca/lorica, has demonstrated the accuracy of his morphological observations (Townsend & Huisman 2021). Townsend and Huisman are generous in their praise of his diligence and his efforts to stay as well informed as possible in the antipodes, in a time when most things came by sea.

Playfair (1916a) on *Oocystis* and *Eremosphaera* has been largely passed over. Ling & Tyler (2000) do not cross-reference his treatment. Playfair was clearly still wrestling with the impact of polymorphism on speciation: '*I do not, however, consider any of the species of* Oocystis *to be biologically distinct, but merely polymorphic forms of one organism. It may be argued that the various types always retain their specific characteristics. They do, and they do not.*' (Playfair 1916a: 109).

Playfair's (1919) work on freshwater dinoflagellates remains the baseline study on this continent. Moestrup & Calado (2018) give him a favourable mention: "*Australia was put firmly on the freshwater dinoflagellate map by George Israel Playfair (1871–1922) …It will be interesting to compare Playfair's many forms and species with material from elsewhere using molecular methods.*" (Moestrup & Calado 2018: 10–11).

Playfair (1921) is another monograph-like treatment, but with a wider scope, green flagellates of many kinds. He was still unsure how biologically sound all the varieties and forms he and his contemporaries describe really are: '*…the rarer varieties, on the other hand, are generally polymorphic forms without any local attachment whatever, but merely the result of unusual combinations of rain and shine, temperature, movement and stagnation in their habitat. In a very large number of cases also, they are simply stages of growth which have become fixed at that point either by the induration of the cell-wall or by the lack of any stimulus to further growth.*' (Playfair 1921: 99).

The Census

Maiden had already included Playfair in his plans for the Census (Maiden 1913: 15) before Playfair left for Lismore. The *Census of New South Wales Fresh-water Algae* (Playfair 1917) is a comprehensive list of his findings to that date, with minor contributions from others, and became the baseline for freshwater algal work in the state. Unfortunately, it does not provide localities, but these can be found through the references to his papers. The nomenclature is current for the time of publication. Given the isolation of the researcher, and where he was working, it is a remarkable document, really not bettered until Day *et al.* (1996).

For a detailed list of published described taxa by Playfair see Table 20 in Cowan & Ducker (2007).

There are preliminary notes and drawings for work on planktonic Cyanobacteria, and some notes on his New Zealand gatherings, including from Dunedin.

He had collated a set of drawings for a paper on *Scenedesmus*. When these were returned to the National Herbarium of New South Wales around 1970, they inspired Valerie May to include the information, together with her own work from across the state, in May (1973). Although Playfair's drawings were not included, May called them: *a valuable series of drawings by the late G.I. Playfair, Australia's foremost student of freshwater algae* (May 1973: 432). She went on: *It is useful to combine various literature references and information from Playfair's extensive drawings with my own observations* (May 1973: 433).

In a gentler paced time, with less complex value systems, where fun was a performance and experiences were shared face to face, George Israel Playfair was a success. As a Congregational Minister he had the personality and drive, and the appropriate level of the common touch, to make a real success of things. He appears, from the local newspaper snippets, to have been a really nice bloke. Both in Auburn *(Auburn News*, Saturday 11 March 1905: 4) and in the Richmond region *(Northern Star*, Tuesday 31 May 1921: 4), he succeeded with the ordinary parishioners.

We have his list to whom he sent 'separates', his word for reprints. There are Swedes and Germans, French and Italians, and British and Americans, as well as Dr Edward Sutherland Stokes (NSW Government Medical Officer), Marjorie Isabel Collins, a Macleay Fellow, and Alfred Douglas Hardy in Melbourne. He also sent his work to his father and uncle. He also corresponded with Arthur Henry Shakespeare Lucas but doesn't record if they exchanged papers. Sadly, we don't have many letters in the NSW collection.

J.H. Maiden's comments from 1913 are worth quoting in full: *The Rev G.I. Playfair, in honorary charge of this section, left Sydney in August last, and to my great regret, relinquished his honorary work for the Herbarium.*

He was almost a solitary worker on these plants in New South Wales. He has left a register, and bottles containing all the species and varieties referred to. The register is charmingly neat, an example to all workers in this respect. (Maiden, 1913, p12).

Playfair's careful critical observations, his careful reading of the latest literature, backed up by well executed illustrations, demonstrate he was a competent biologist, and well able to keep up with his peers. Gustavus Athol Waterhouse noted in his obituary: …*he was one of those who was always willing to talk freely of his work, but said little about himself* (Waterhouse 1923: vii).

It is as a natural historian that he shines. His careful observations laid the groundwork for later taxonomists and ecologists to follow. He didn't have the opportunity to gain the training in experimentation, or the support to make the step to ecologist level. His contribution to our general understanding of freshwater microorganism diversity in our inland waters has yet to be surpassed.

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Recircumscription of *Utricularia leptorhyncha* and *U. lasiocaulis* and three related new species for northern Australia

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Abstract

The *Utricularia lasiocaulis* F.Muell. complex (subg. *Polypompholyx*; sect. *Lasiocaules*) is a morphologically and ecologically variable group of closely related taxa with a mostly tropical distribution across northern Australia. A recent molecular phylogenetic study placed the recognised species *U. kamienskii* F.Muell. sister to a clade of accessions relegated to either *U. leptorhyncha* O. Schwarz or *U. lasiocaulis*, with the latter previously circumscribed as an assemblage of highly variable morphological forms. We have expanded the previous study to include populations representing the known distributions of all three species and have attempted to include all morphological variants; 55 ingroup accessions were used in the full phylogenetic analysis based on two non-coding chloroplast regions (*rps*16, *trn*D–T) and the nuclear ribosomal internal transcribed spacer (ITS). We found that the pink corolla form of the usually white flowered *U. kamienskii* is not sufficiently different, and we retain it under that species. We also found strong support for a paraphyletic *U. leptorhyncha*, with the smaller flowered accessions matching the type material placed sister to all other *U. lasiocaulis* forms, including a grouping previously assigned as a larger flowered *U. leptorhyncha*. Within the *U. lasiocaulis* clade we found that much of the variation sorts into well-supported clades that we find are sufficiently morphologically and genetically differentiated from the type clade for recognition at the specific rank, namely *Utricularia brennanii* R.W.Jobson & Baleeiro from Northern Territory and Queensland, *Utricularia cowiei* R.W.Jobson & Baleeiro from the Kimberley region of Western Australia, and *U. disjuncta* R.W.Jobson & Baleeiro restricted to the Darwin and Gulf region of the Northern Territory.

Introduction

Taylor (1989) placed *U. leptorhyncha O.Schwarz* and *Utricularia lasiocaulis* F.Muell within section *Pleiochasia* Kamienski of subgen. *Polypompholyx* sensu Muller *et al*. (2005), with Jobson et al. (2017) designating the phylogenetic clade containing these two species sect. *Lasiocaules* R.W.Jobson & Baleeiro. Jobson et al. 2017 assigned as Clade D the *U. kamienskii-U. leptorhyncha-U. lasiocaulis* group that was estimated to have diverged from its most recent common ancestor at ~10 Ma in the late Miocene. The same study estimated the

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divergence of *U. kamienskii* from sister species *U. leptorhyncha-U. lasiocaulis* at ~5 Ma and *U. leptorhyncha* from *U. lasiocaulis* at ~2 Ma - both in the Pliocene.

Under Taylor's circumscription of *U. leptorhyncha* the distribution extended from the Kimberley, WA to Top End, NT (Fig. 1). Subsequent removal of two taxa from under *U. leptorhyncha*, namely *U. bidentata* R.W.Jobson & Baleeiro and *U. papilliscapa* R.W.Jobson & M.D.Barrett (Jobson et al. 2018), limited the distribution of the here redescribed species to the Top End, NT (Fig. 1). The holotype representing *U. leptorhyncha* collected by Florenz Bleeser (*F.A.K.Bleeser 145*) 4 miles NE of Port Darwin, was destroyed in the Berlin Herbarium (B). Subsequently, Peter Taylor (1989) selected a neotype apparently matching the protolog that was collected near Berry Springs, c. 32 km SSE of Darwin by Laurance Adams (Fig. 5; *L.G.Adams 1722* (K)).

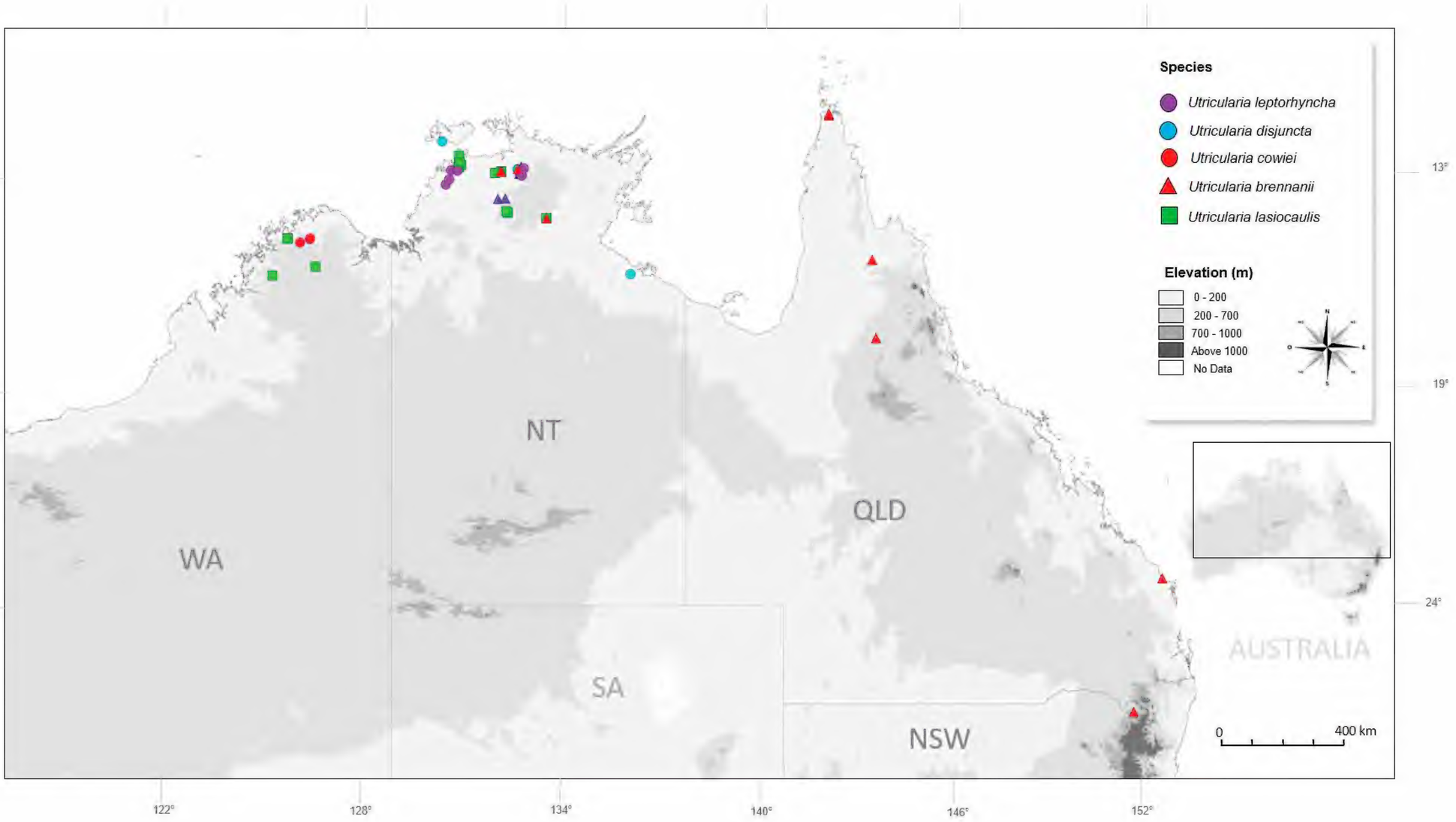

Fig. 1. Distribution map showing accessions used in the molecular phylogeny of *Utricularia lasiocaulis* and allied species: *U. kamienskii* (blue triangle), *U. leptorhyncha* (purple circle), *U. lasiocaulis* (green square), *U. brennanii* (red triangle), *U. cowiei* (red circle), *U. disjuncta* (light-blue circle). For accession details refer to Table 1.

Taylor's (1989) description and illustration were based on a combination of *U. leptorhyncha* and the superficially similar and recently described species *U. papilliscapa* R.WJobson & M.D.Barrett from the northern Kimberley region of Western Australia (Jobson et al. 2018). *Utricularia papilliscapa* was partially illustrated and described in Taylor (1989) within the description of *U. leptorhyncha*: *Utricularia papilliscapa* = (fig. 27: 2–6, 8, 10–14 from *Dunlop 5319*); *U. leptorhyncha* = (fig. 27: 1, 7, 9, 15, 16 from *Craven 2493* – fitting the neotype *Adams 1722*).

Taylor's (1989) concept of *U. lasiocaulis* involved a large assemblage of highly variable morphological forms that differed mainly in corolla shape and size and hairiness of the peduncle ranging from basal to complete indumentum. The holotype representing *Utricularia lasiocaulis* F.Muell. was collected by Maurice Holtz at the Port of Darwin in 1885 (Fig. 7; *Holtz 477*, MEL1513419), and was recently assigned as type for section *Lasiocaules* (Jobson et al. 2017). In the notes of the attached protologue (originally published by Holtz in *Aust. Druggist and Chemist*, pp. 50, Oct. 1885), the major characteristic appears to be the downy indumentum of the peduncle and the bracts and bracteoles with ciliated margin (Figs 4, 5).

The current study assesses taxonomic limits within the *U. lasiocaulis* species complex (as circumscribed by Taylor (1989)) and closely allied species, with wide sampling across the geographic distribution of the complex (Table 1; Fig. 1). Phylogenetic relationships are assessed using Bayesian inference analyses of DNA sequences representing the plastid *rps*16 and *trn*D–T introns, and the nuclear ribosomal internal transcribed spacer (ITS) (Table 1; Fig. 2). Using the phylogenetic hypothesis, we examine whether a pink corolla form of *U. kamienskii* that occupies creeks on sandstone outcrops and plateaus of Arnhem Land is genetically distinct from the common white flowered form that occupies lowland sand flats and grasslands across the Top End.

Table 1. Accessions used in the ITS and cpDNA matrices. Secondary collectors are not included. Locality abbreviations: NSW, New South Wales; NT, Northern Territory; Qld, Queensland; WA, Western Australia. GenBank accession numbers for each sequence are shown. NS indicates sequence that either failed or were not included in the study. Genbank numbers preceded by "KY" were used in Jobson et al. (2017).

Code	Taxon	Voucher	Locality	rps16	trnD-T	ITS
434	*U. kamienskii* F.Muell.	I.D Cowie 9126 (DNA)	Howard River, NT	KY243477	KY243770	OP442582
435	*U. kamienskii* F.Muell.	R.W. Jobson 2242 (NSW)	Girraween, NT	KY243478	KY243771	NS
436	*U. kamienskii* F.Muell.	D.E. Murfet 5964 (AD)	Girraween, NT	KY243479	KY243772	NS
1078	*U. kamienskii* F.Muell.	R.W. Jobson 3953 (NSW)	Girraween, NT	OP437429	OP437459	NS
1083	*U. kamienskii* F.Muell.	R.W. Jobson 3961 (NSW)	Howard River Floodplain, NT	OP437433	OP437463	NS
1091	*U. kamienskii* F.Muell.	R.W. Jobson 2200 (NSW)	Near Koymarrwa Lookout, NT	OP437438	OP437468	NS
1096	*U. kamienskii* F.Muell.	M. Lazarides 8998 (CANB)	NE Jabiru, NT	OP437442	OP437472	NS
1097	*U. kamienskii* F.Muell.	L.A. Craven 6579 (CANB)	SE Jabiru, NT	OP437443	OP437473	NS
1098	*U. kamienskii* F.Muell.	J. McAuliffe 2109 (CANB)	Mt Brockman, NT	OP437444	OP437474	NS
1120	*U. kamienskii* F.Muell.	L.A. Craven 6579A (CANB)	17km SE Jabiru, NT	OP437446	OP437476	NS
1124	*U. kamienskii* F.Muell.	I.D. Cowie 2833 (DNA)	Kurundie Creek, NT	OP437448	OP437478	NS
921	*U. leptorhyncha* O.Schwartz	R.W. Jobson 3198 (NSW)	Finnis River, NT	KY243578	KY243872	OP442596
963	*U. leptorhyncha* O.Schwartz	I.D. Cowie 9706 (DNA)	Wangi Falls, NT	NS	OP902896	NS
964	*U. leptorhyncha* O.Schwartz	I.D. Cowie 9695 (DNA)	Cox Peninsula, NT	NS	OP902897	NS
966	*U. leptorhyncha* O.Schwartz	J.L. Egan 4585 (DNA)	Mount Brockman, NT	NS	OP902899	NS
969	*U. leptorhyncha* O.Schwartz	G.J. Leach 2553 (DNA)	Mt Howship, NT	OP437454	OP437484	NS
1079	*U. leptorhyncha* O.Schwartz	R.W. Jobson 3955 (NSW)	Berry Springs, NT	OP437430	OP437460	OP442573
1088	*U. leptorhyncha* O.Schwartz	R.W. Jobson 3977 (NSW)	Finnis River, NT	OP437436	OP437466	OP442577
1099	*U. leptorhyncha* O.Schwartz	K.G. Brennan 3022 (DNA)	Jabiru airstrip, NT	OP437445	OP437475	NS
447	*U. lasiocaulis* F.Muell.	R. Gilliland 66 (NEU)	Howard Springs, NT	KY243488	KY243781	NS
450	*U. lasiocaulis* F.Muell.	R.W. Jobson 2225 (NSW)	Flying Fox Ck, NT	KY243490	KY243783	NS
452	*U. lasiocaulis* F.Muell.	R.W. Jobson 2261 (NSW)	Mitchell Plateau, WA	NS	NS	OP442584
544	*U. lasiocaulis* F.Muell.	R.W. Jobson 3292 (NSW)	Girraween, NT	KY243521	NS	NS
891	*U. lasiocaulis* F.Muell.	R.W. Jobson 2690 (NSW)	Mt Bundey, NT	KY243562	KY243856	OP442591
894	*U. lasiocaulis* F.Muell.	R.W. Jobson 2703 (NSW)	Gunn Peninsula, NT	KY243565	KY243859	OP442593
919	*U. lasiocaulis* F.Muell.	R.W. Jobson 3188 (NSW)	Darwin, NT	KY243576	KY243870	NS
920	*U. lasiocaulis* F.Muell.	R.W. Jobson 3197 (NSW)	Finnis River, NT	KY243577	KY243871	OP442595
958	*U. lasiocaulis* F.Muell.	C.R. Michell 4115 (DNA)	Murrawal Plateau, NT	OP437450	OP437481	NS
959	*U. lasiocaulis* F.Muell.	K.G. Brennan 6325 (DNA)	Ellenbrae Station, WA.	OP437451	OP437482	OP442597
961	*U. lasiocaulis* F.Muell.	I.D. Cowie 9534 (DNA)	Fergusson River, NT	OP437452	OP437483	NS
998	*U. lasiocaulis* F.Muell.	C. Bugden CDT12 (PERTH)	Bachsten Creek, WA	OP437457	OP437486	NS
1004	*U. lasiocaulis* F.Muell.	G.J. Keighery 1687 (PERTH)	Mitchell Plateau, WA	NS	NS	OP442571
1081	*U. lasiocaulis* F.Muell.	R.W. Jobson 3958 (NSW)	Noonamah, NT	OP437431	OP437461	OP442574
1082	*U. lasiocaulis* F.Muell.	R.W. Jobson 3960 (NSW)	Gunn Point Rd., NT	OP437432	OP437462	NS
1089	*U. lasiocaulis* F.Muell.	R.W. Jobson 3978 (NSW)	Finnis River, NT	OP437437	OP437467	OP442578
1094	*U. lasiocaulis* F.Muell.	R.W. Jobson 4021 (NSW)	Flying Fox Creek, NT	OP437440	OP437470	OP442580
1122	*U. lasiocaulis* F.Muell.	K.G. Brennan 3183 (CANB)	West Alligator River, NT	OP437447	OP437477	NS
449	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 2036 (NSW)	Bundaberg, Qld	KY243489	KY243782	NS
451	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 2226 (NSW)	Flying Fox Ck, NT	KY243491	KY243784	OP442583
456	*U. brennanii* R.W.Jobson & Baleeiro	R. Fensham 4506 (BRI)	Einasleigh River, Qld	KY243493	KY243786	NS
679	*U. brennanii* R.W.Jobson & Baleeiro	G. Bourke 112 (NSW)	Jackey Jackey Creek, Qld	KY243544	KY243841	OP442588
892	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 2691 (NSW)	Mt bundey, NT	KY243563	KY243857	OP442592
909	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 2845 (NSW)	Laura, Qld	KY243571	KY243865	OP442594
1077	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 3777 (NSW)	Bamaga, Qld	OP437428	OP437458	OP442572

Code	Taxon	Voucher	Locality	rps16	trnD-T	ITS
1092	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 4019 (NSW)	Jabiru Aerodrome, NT	OP437439	OP437469	OP442579
1095	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 4022 (NSW)	Flying Fox Creek, NT	OP437441	OP437471	OP442581
1128	*U. brennanii* R.W.Jobson & Baleeiro	R.W. Jobson 4188 (NSW)	Fruitbat Falls, Qld	OP437449	OP437479	NS
453	*U. cowiei* R.W.Jobson & Baleeiro	M.D. Barrett 2775 (PERTH)	Harding Range, WA	KY243492	KY243785	OP442585
874	*U. cowiei* R.W.Jobson & Baleeiro	R.W. Jobson 2658 (NSW)	King Edward River, WA	KY243552	KY243847	OP442589
878	*U. cowiei* R.W.Jobson & Baleeiro	R.W. Jobson 2668 (NSW)	Theda Station, WA	KY243554	KY243849	OP442590
458	*U. disjuncta* R.W.Jobson & Baleeiro	R.K. Harwood 1046 (DNA)	Girraween, NT	GQ478684	KY243787	OP442586
462	*U. disjuncta* R.W.Jobson & Baleeiro	D.E. Murfet 5641 (AD)	Noonamah Jenkins Rd., NT	NS	OP437480	OP442587
965	*U. disjuncta* R.W.Jobson & Baleeiro	K.G. Brennan 9063 (DNA)	Bathurst Island, NT	OP437453	OP902898	NS
970	*U. disjuncta* R.W.Jobson & Baleeiro	I.D. Cowie 9061 (DNA)	Gunn Point Rd., NT	OP437455	OP902900	OP442598
994	*U. disjuncta* R.W.Jobson & Baleeiro	R.W. Jobson 3438 (NSW)	Bing Bong, NT	OP437456	OP437485	OP442599
1084	*U. disjuncta* R.W.Jobson & Baleeiro	R.W. Jobson 3962 (NSW)	Howard River Floodplain, NT	OP437434	OP437464	OP442575
1085	*U. disjuncta* R.W.Jobson & Baleeiro	R.W. Jobson 3965 (NSW)	Girraween, NT	OP437435	OP437465	OP442576
911	*U calycifida* Benj.	R.W. Jobson 3119 (NSW)	Brazil (ex situ)	MH036231	MH030265	MH030211
564	*U. tubulata* F.Muell.	R.W.Jobson 2315 (NSW)	Dampier Penninsula, WA	KY243533	KY243829	MK259942
884	*U. minutissima* Vahl	R.W.Jobson 2676 (NSW)	Mitchell Plataeu, WA	KY243502	KY243796	NS

We also provide an updated taxonomic description for *U. leptorhyncha* now restricted to the Darwin and Jabiru regions of Northern Territory, and *U. lasiocaulis* that is distributed from the Kimberly region of Western Australia to Darwin and Jabiru regions of Northern Territory (Fig. 1, 3). These descriptions involve accessions best fitting the respective type material (Figs 5, 7).

Based on morphology and the above mentioned phylogenetic hypothesis, we here describe the new species *Utricularia brennanii* R.W.Jobson & Baleeiro from Northern Territory and Queensland, *U. cowiei* R.W.Jobson & Baleeiro from the North Kimberly region of Western Australia, and *U. disjuncta* R.W.Jobson & Baleeiro restricted to the Darwin, Bathurst Island, and Gulf region of the Northern Territory (Fig. 3). Morphological differences are compared between the newly described entities and their closely allied species, with notes on distribution, ecology and conservation status provided. An identification key representing the related species of section *Lasiocaules* is provided.

Methods

Taxon sampling and DNA extraction

We sampled from 58 accessions comprising silica-dried and herbarium-sheet material, including three outgroup and 55 ingroup samples from across the distribution of the study group, representing *U. kamienskii* (n = 11), *U. leptorhyncha* (n = 8), and *U. lasiocaulis* and all known forms and variants (n = 36) (Table 1).

DNA isolation was performed as for Jobson *et al.* (2017). Outgroup taxa were selected based on Jobson *et al.* (2017). The final dataset contained 55 ingroup accessions, of which 23 were used in Jobson *et al.* (2017; Fig. 2, Table 1). Location details of all accessions were used to create a distribution map (Fig. 1). Scientific collection permits were obtained from relevant State and Federal Government agencies.

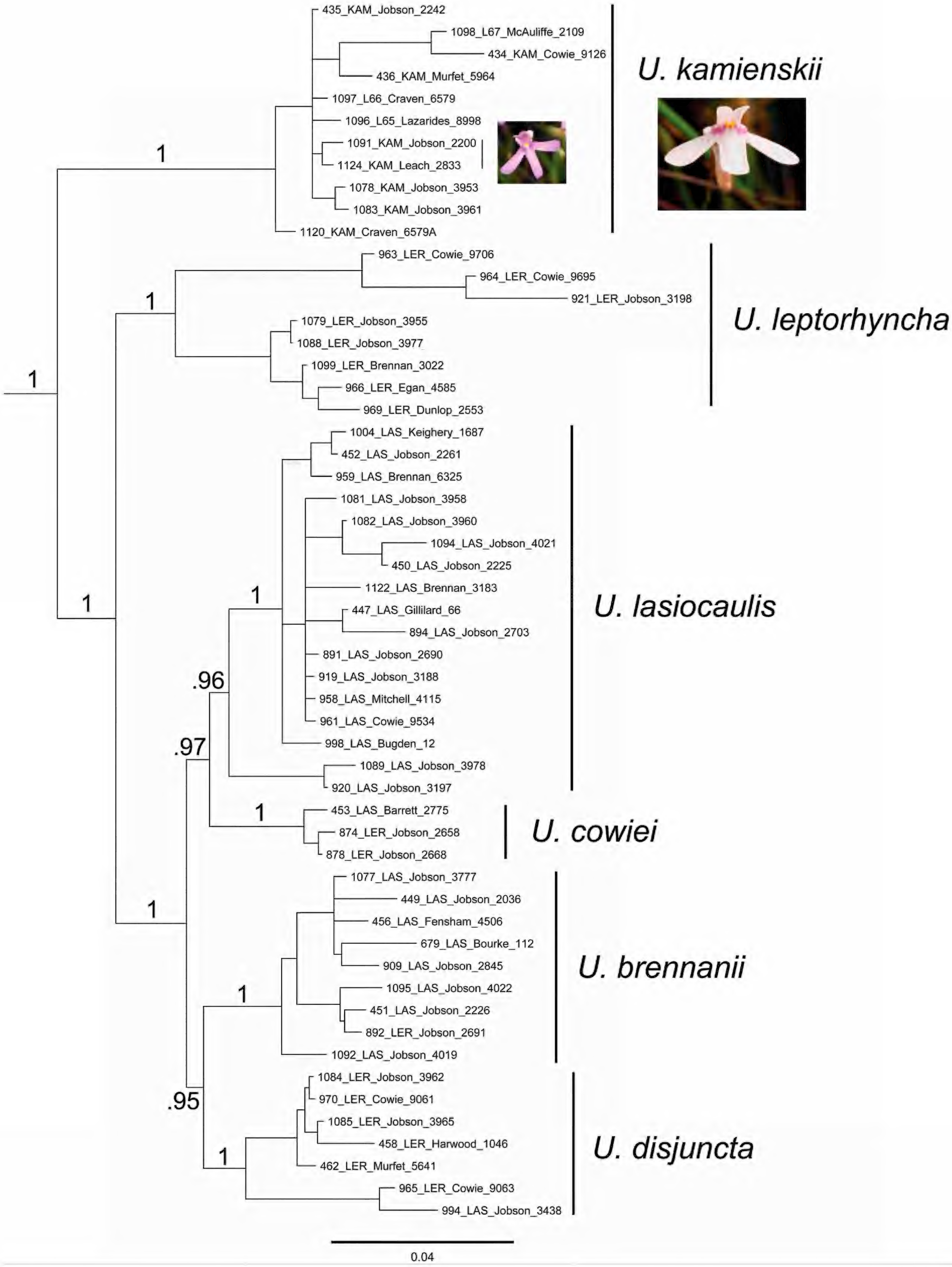

Fig. 2. 50% majority-rule Bayesian inference consensus tree for the concatenated plastid/nuclear (Cp/Nu) DNA matrix. Posterior probability (PP) support values for Cp/Nu analysis are shown above important branches. PP = 1–0.95: strong support; 0.94–0.85: weak support (not shown); unsupported (not shown). Thin bar shows two accessions and representative image of the pink form of *U. kamienskii* with an image of typical white form shown at bar representing *U. kamienskii* clade.

Amplification and sequencing

Amplifications were performed as for Jobson *et al.* (2017), using two non-coding plastid (cpDNA) and the nuclear (nuDNA) ribosomal gene marker. The cpDNA markers included the *rps*16 intron amplified using parameters described in Oxelman *et al.* (1997), whereas the *trn*D–*trn*T intron spacer (*trn*D–T) was amplified using parameters described in Shaw *et al.* (2005).

These cpDNA markers have been shown to provide enough information to resolve relationships at the species and intraspecific level across *Utricularia* (Jobson *et al.* 2017). The nuclear ribosomal ITS region was amplified using the forward primer ITS5A (Stanford et al. 2000) and the universal internal reverse primer ITS2, and reverse primer ITS4 (White *et al.* 1990). Polymerase chain reaction (PCR) conditions for ITS were performed as described in White *et al.* (1990). Forward and reverse sequences were assembled and edited as for Jobson & Davies-Colley (2020).

Phylogenetic analyses

Phylogenetic analyses were performed on (1) the three individual datasets, (2) the combined cpDNA and (3) a concatenated matrix comprising all three markers. The most suitable nucleotide substitution model for each of the three markers was assessed using the Akaike information criterion (AIC) implemented in jModelTest (ver. 2.1.7, see https://en.bio-soft.net/tree/MODELTEST.html, accessed 12 July 2022; Guindon and Gascuel 2003; Posada 2008). The best fit was GTR+ I+G and GTR+G for the cpDNA and nuDNA markers, respectively.

With a burn-in involving the first 25% of the samples, we estimated Bayesian posterior probability with five independent runs of 10 million generations, using four chains with sampling of trees every 1000 generations. All parameters were set as Dirichlet; with all other priors unlinked with a flat multinomial distribution. Stationarity was assessed by examining plots of the –lnL across generations in Tracer (ver. 1.6, A. Rambaut, M. A. Suchard, D. Xie and A. J. Drummond, see http://beast.bio.ed.ac.uk/Trace, accessed 20 19 July 2022). The effective sample size (ESS) was set to >1000, and the remaining trees were used to construct a 50% majority-rule consensus tree, visualised using FigTree (ver. 1.4.0).

Specimen examination

Relevant dried and alcohol-preserved material representing all related species, held at the National Herbarium of New South Wales (NSW), Australian National Herbarium (CANB), Northern Territory Herbarium (DNA), Western Australia Herbarium (PERTH), State Herbarium of South Australia (AD), and Queensland Herbarium (BRI) were examined.

Results

Sequences and alignment

The *rps16* matrix was 937 bp long, of which 104 characters (11%) were parsimony informative, *trnD-T* matrix was 941 bp long, of which 78 characters (8.3%) were parsimony informative, and the ITS matrix was 855 bp long of which 316 characters (37%) were parsimony informative. All three datasets included members of all ingroup taxa; *rps16* (n = 51), *trnD-T* (n = 53), ITS (n = 29) (Table 1). The concatenated three gene matrix contained 55 ingroup and three outgroup taxa and was 2647 bp long with 498 parsimony informative characters (19%).

Phylogenetic relationships

The separately analysed ITS and the combined *rps16/trnD-T* trees were largely topologically congruent, and both datasets were concatenated and analysed together as a single matrix (Fig. 2). The 50% consensus tree showed strongly supported monophyletic major clades (posterior probability (PP) = 1) representing *U. kamienskii*, *U. leptorhyncha* and *U. lasiocaulis* (Fig. 2). Figure 2 also shows that the pink-corolla form of *U. kamienskii* is nested within a strongly supported assemblage of typical white-corolla forms that match the type material for this species. Three additional clades were observed within the *U. lasiocaulis* assemblage, namely *U. cowiei* which was sister to *U. lasiocaulis* sensu str., and together these were sister to a clade containing the strongly supported groupings of *U. brennanii* and *U. disjuncta* (Fig. 2).

Taxonomy

Utricularia leptorhyncha O.Schwarz, *Feddes Repert*. 24: 97 (1927)

Type: 4 miles NE of Port Darwin, N.T., *F.A.K.Bleeser 145*; holo: B (destroyed); neo: near Berry Springs, c. 32 km SSE of Darwin, *L.G.Adams 1722* (K), designated by P.Taylor, *Kew Bull. Add. Ser.* 14: 148 (1989).

Small to medium sized annual, terrestrial herb. *Rhizoides* capillary, simple, up to 3 mm long, 0.1 mm thick at base tapering to 0.05 mm near the apex, numerous from the peduncle base, 1 or 2 from stolon nodes. *Stolons* few, branched, filiform, 0.1–0.12 mm thick, internodes 4–5 mm long. *Leaves* numerous, few at peduncle base and 2–3 on stolon nodes, petiolate, lamina spatulate, 1.5–3 mm long, 0.6–1.5 mm wide, single nerve, apex rounded, total length up to 5.5 mm long. *Traps* stalked, ovoid, 0.8–1.1 mm long; 1 at nodes and on internodes; uniform, mouth lateral with a simple dorsal appendage 0.15 mm long, and two lateral appendages c. 0.15 mm long, ventral wings 0.1 mm long with shallowly dentate margin. *Inflorescence* solitary, 70–160 mm long; flower solitary, paired, or rarely three in a whorl, arising in succession; peduncle erect, solid, terete, hirsute for 1/5 from base of peduncle then glabrous, 0.2–0.3 mm thick. *Scales* absent; *bract and bracteoles* equal, basifixed, gibbous at base, lanceolate, 0.5–0.7 mm long, c. 0.3 mm wide, entire margin, apex acute. *Pedicel* erect, filiform, tapering apically 14–40 mm long. *Calyx* lobes unequal; upper lobe ovate, 1.6–1.8 mm long, 1.4–1.7 mm wide; lower lobe shorter, narrowly ovate, with apex bilobed 1.3–1.5 mm long, 1.2–1.4 mm wide. *Corolla* 5–7 mm long, upper side light violet, underside white; *upper lip limb* constricted near the middle where bent upwards at c. 90°, 1.5–2.1 mm long, superior part obovate with apex emarginate or bilobed, inferior part ovate with margin ciliate; *lower lip limb*, narrowly obovate in outline with apex rounded or acute, 7–9 mm long, 4.5–5.5 mm wide, deeply to shallowly 3-lobed; base of lower lip with two white, slightly raised ridges, with 2 longer dark violet rimmed white streaks either side; *spur* usually projecting c. 90°–110° to the lower lip, conical in cross-section at the base, subulate, tapering to an acute apex, 4.2–5.0 mm long, c. 1.1 mm wide near middle, shorter or slightly longer than the length of lower lip. *Capsule* globose, c. 2.1 mm in diameter, dehiscing from a longitudinal, ventral, marginally thickened slit. *Seeds* obovoid, c. 0.3 mm long. *Pistil* c. 1.2 mm long; *Filaments* curved c. 1.1 mm long. *Pollen* 3-colporate. Figures 3a–b, 4, 5.

Additional specimens examined: AUSTRALIA: Northern Territory: 15 km SW of Mount Howship, Arnhem Land, *Leach G.J. 2553*, 18 Apr 1989 (DNA); 24.5 km SSE Jabiru airstrip, *Brennan K. 3022*, 18 Mar 1995 (DNA); Kakadu NP, Mount Brockman, *Egan J.L. 4585*, 29 Mar 1995 (DNA); Kakadu Fire Plot 140, *Brennan K. 3840*, 24 Apr 1999 (DNA); Cox Peninsula Rd, near upper Charlotte R., *Cowie I.D. 9695*, 25 Mar 2003 (DNA); Litchfield NP, N of Wangi Falls TO, Cowie I.D. 9706, 27 Mar 2003 (DNA); S of Hwy on Hopewell Rd, Berry Springs, *Jobson R.W. 3955*, 19 Mar 2021 (NSW1119729); Finnis River along Litchfield Park Rd, *Jobson R.W. 3977*, 22 Mar 2021 (NSW1119728).

Distribution, Ecology & Phenology: Widespread across the Top End, Northern Territory (Fig. 1). Grows in wet sand in seasonal swamps and creeks. Flowers and fruit were observed from February–September.

Conservation Status: Widespread across the Top End, and populations appear to be locally common. It is, therefore, recommended that this species be listed in Northern Territory as Least Concern.

Notes: When observed in the field *U. leptorhyncha* resembles *U. disjuncta* in having a white lower corolla under-side and upper corolla-lip but differs in the size of the corolla 5–7 mm vs. 10–14 mm long, and the lack of ciliate margin on ventral bladder-trap wings make it unlikely to be confused with it or any related species (Fig. 3 c–d, 6, 7). *Utricularia leptorhyncha* was illustrated and described in Taylor (1989) (= fig. 27: 1, 7, 9, 15, 16 from *Craven 2493* fitting the type *Adams 1722*), although much of the description and illustration involved accessions from WA (= fig. 27: 2–6, 8, 10–14 from *Dunlop 5319*) that was recently shown in the molecular phylogeny of Jobson et al. (2017) to be a novel taxon that was subsequently described as *U. papilliscapa* R.W.Jobson & M.D.Barrett in Jobson et al. (2018).

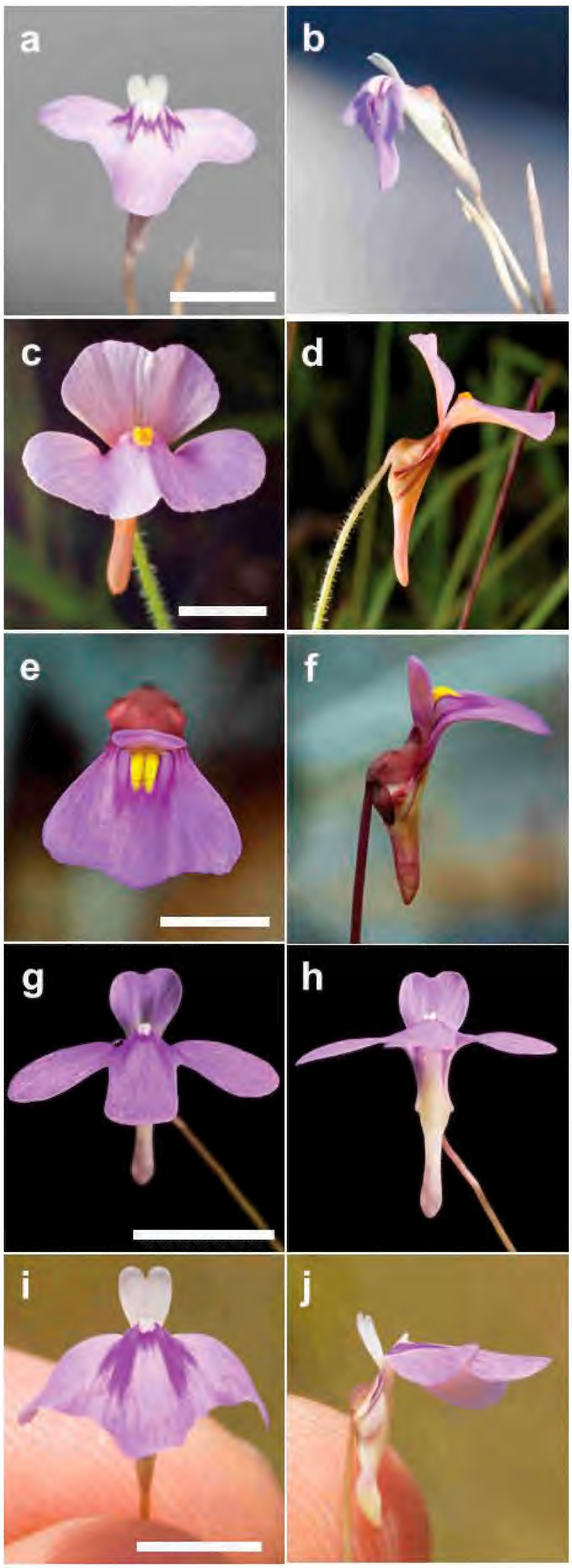

Fig. 3. *Utricularia leptorhyncha* (a, b), *U. lasiocaulis* (c, d), *U. brennanii* (e, f), *U. cowiei* (g, h) and *U. disjuncta* (i, j): a, c, e, g, i, corolla frontal view; b, d, f, j, corolla lateral view; h, spur frontal view. Scale bars: a–j = 5 mm. Images: c, d, g & h by W. Cherry; e, f by G. Bourke; a,b, i & j by R.W. Jobson.

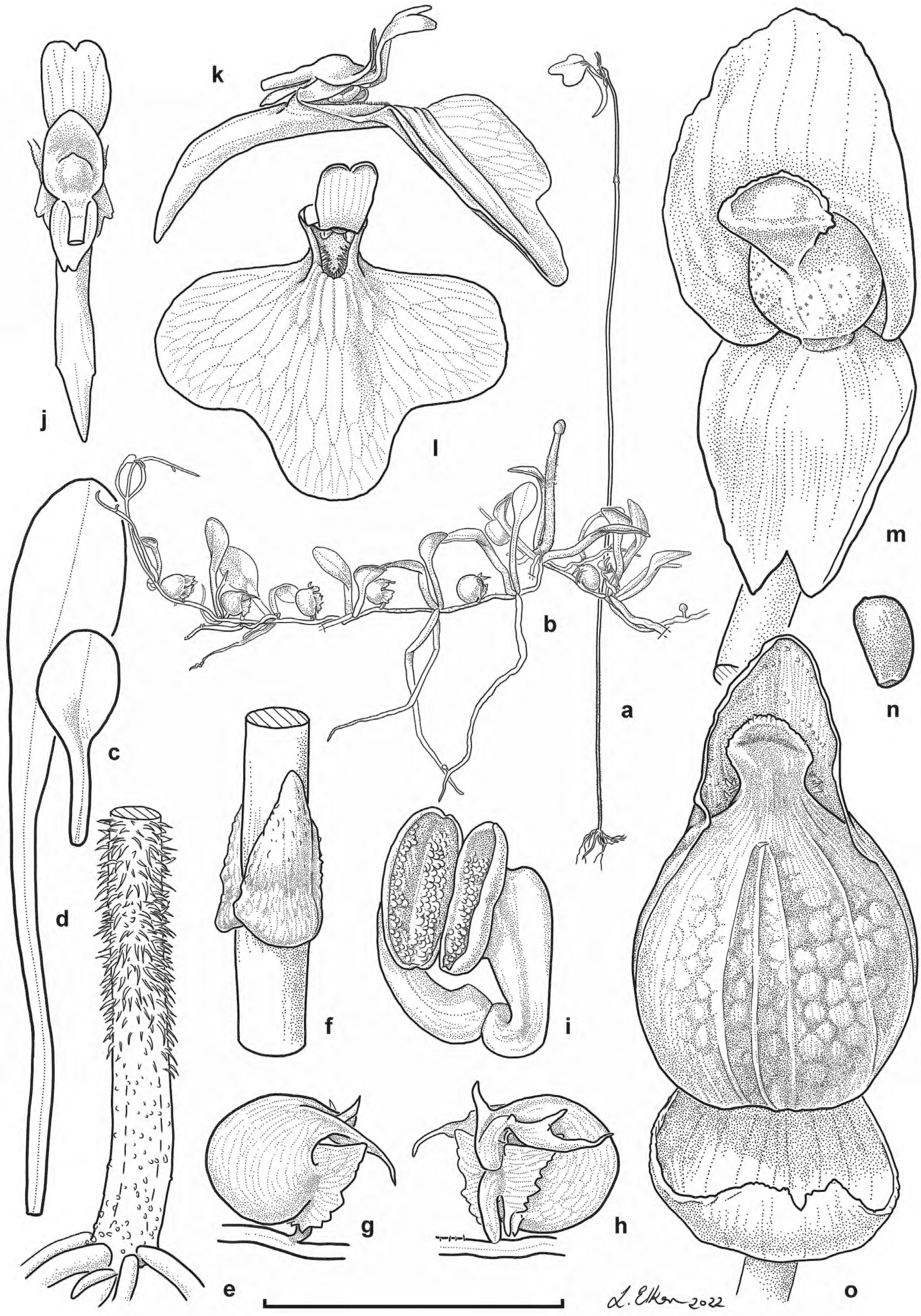

Fig. 4. *Utricularia leptorhyncha*. a, habit; b, stolon with vegetative parts and peduncle base in situ; c, leaf adaxial surface; d, large leaf adaxial surface; e, peduncle base; f, bract and bracteoles; g, bladder-trap lateral view; h, bladder-trap dorsal view; i, stamen frontal view; j, flower dorsal view; k, flower lateral view; l, flower frontal view; m, calyx with ovary; n, seed; o, fruit ventral view. Scale bar: a = 33.3 mm; b = 10 mm; c & d = 3.3 mm; e & i = 1.67 mm; f-h, m & o = 2 mm; j-l = 7 mm; n = 1 mm. Material used: *Jobson 3977 & Baleeiro* (NSW834756).

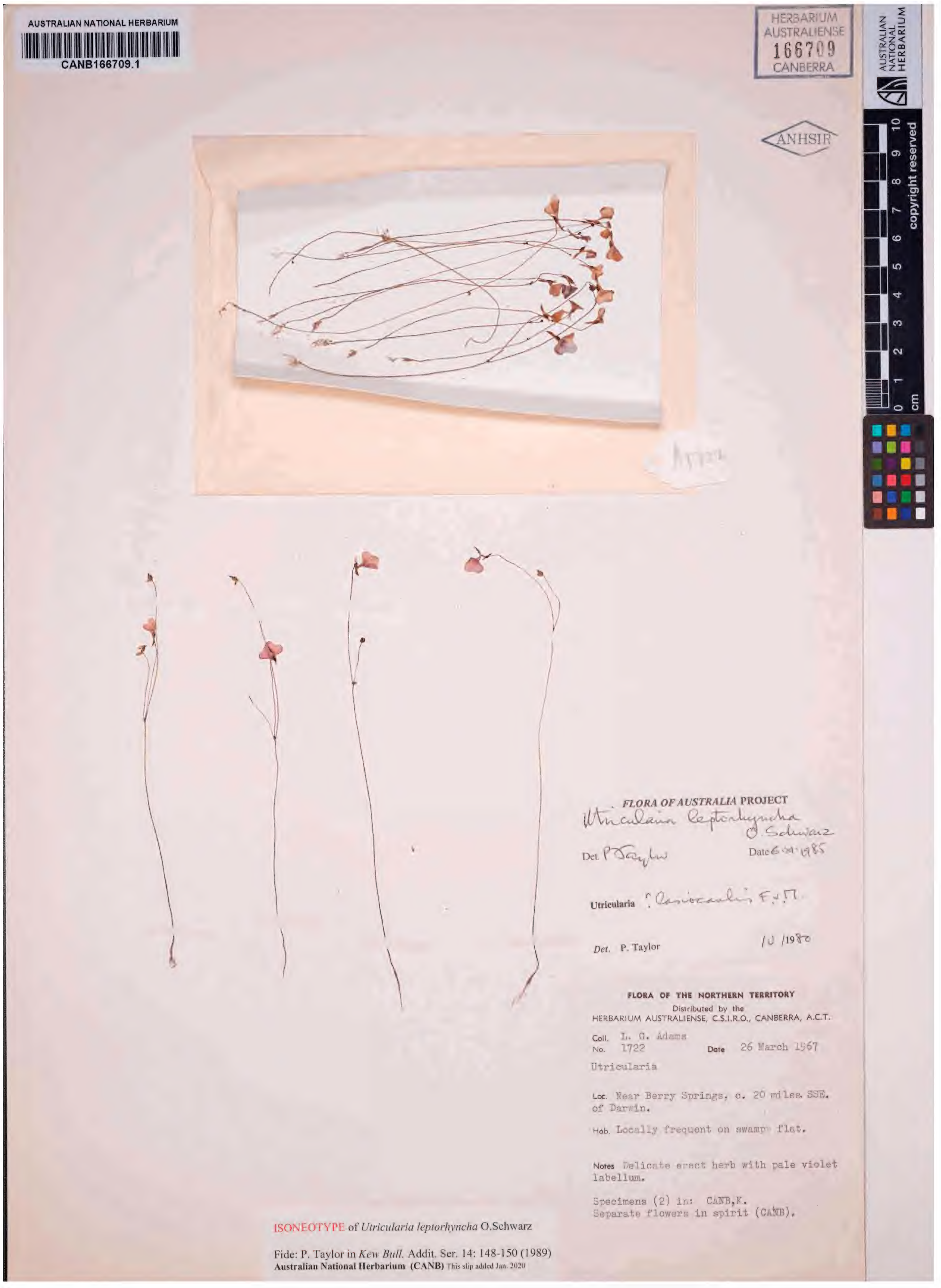

Fig. 5. Isoneotype of *Utricularia leptorhyncha* O.Schwarz (*L.G. Adams 1722*; CANB166709)

Utricularia lasiocaulis F.Muell., *Australas. Chem. Druggist, Oct. 1885*: 50 (1885), & *Bot. Centralbl.* 24: 338 (1885)

Type: near Darwin, N.T., *M. Holtze 477*; holo: MEL1513419, iso: AD97705125,

Small to medium sized annual, terrestrial herb. *Rhizoides* capillary, simple, up to 8 mm long, 0.12 mm thick at base tapering to 0.05 mm near the apex, numerous from the peduncle base, 1 or 2 from stolon nodes. *Stolons* few, branched, filiform, c. 20 mm long, 0.16–0.21 mm thick, internodes 2–2.5 mm long. *Leaves* numerous, several at peduncle base and 1 on stolon nodes, petiolate, lamina spathulate, 1–1.2 mm long, 0.4–0.6 mm wide, single nerve, apex rounded, total length up to 2–12 mm long. *Traps* stalked, ovoid, 0.5–2 mm long; 1 at nodes and on internodes; dimorphic, either small and subsessile or large and stalked, mouth lateral with single dorsal and two lateral appendages similar, deltoid, 0.7 mm long, ventral wings larger, broadly deltoid, c. 1.2 mm long, all appendages with ciliate margin. *Inflorescence* solitary, 70–180 mm long; flower solitary, or with two or three pedicles arising in succession; peduncle erect, solid, terete, entirely hirsute or near the base, 0.8–1.1 mm thick. *Scales* absent; *Bract and bracteoles* unequal, basifixed, gibbous at base, bracteoles narrowly lanceolate, 1–1.1 mm long, c. 0.1 mm wide, bract ovate, 0.5–0.6 mm long, c. 0.4 mm wide, ciliate margin around base and apex. *Pedicel* erect or deflexed near apex, filiform, tapering apically 25–42 mm long. *Calyx* lobes unequal; upper lobe ovate, 2.2–2.8 mm long, 2.0–2.5 mm wide; lower lobe shorter, ovate, with apex bilobed 1.4–1.7 mm long, 1.3–1.7 mm wide. *Corolla* 12–18 mm long, upper side pink to dark mauve, underside light to dark orange; *upper lip limb* constricted near the base, 4.8–6.1 mm long, 2.5–5.1 mm wide, superior part transversely elliptic to broadly obcordate with apex entire or bilobed, inferior part ovate with margin ciliate; *lower lip limb*, reniform to obcordate in outline with apex entire, rounded, 10–13 mm long, 10–14 mm wide; base of lower lip with two raised orange or yellow claw-like ridges; *spur* projecting c. 90° to the lower lip, conical in cross-section at the base, subulate, tapering to an acute or rounded apex, 7–11 mm long, c. 2.8 mm wide near base, equal to or slightly longer than the length of lower lip. *Capsule* globose, c. 3.1 mm in diameter, dehiscing from a longitudinal, ventral, marginally thickened slit. *Seeds* cylindrical, c. 0.45 mm long. *Pistil* c. 1.2 mm long; *Filaments* curved c. 1.5 mm long. *Pollen* 3-colporate. Figures 3c–d, 6, 7.

Additional specimens examined: AUSTRALIA: Western Australia: Airfield Swamp, Mitchell Plateau, *G.J. Keighery 1687 & J.J. Alford*, 16 Jun 1987 (PERTH); Ellenbrae Station, *K.G. Brennan 6325 & C.C. Done*, 20 Jul 2004 (DNA); Bachsten Creek, *C. Bugden CDT 12 & al.* 11 Jul 2005 (PERTH); Mitchell Plateau, *R.W. Jobson 2261 & P.C. Baleeiro*, 25 Apr 2014 (NSW852502). NORTHERN TERRITORY: West Alligator River, *K. Brennan 3183*, 28 Apr 1995 (DNA); Nitmiluk NP, *C.R. Michell 4115*, 13 Apr 2002 (DNA); Fergusson River, *I.D. Cowie 9534 & A.K. Gibbons*, 27 Mar 2002 (DNA); Flying Fox Ck, *R.W. Jobson 2225 & P.C. Baleeiro*, 20 Apr 2014 (NSW924481); Mount Bundey, *R.W. Jobson 2690 & W.A. Cherry*, 18 Apr 2015 (NSW927133); Gunn Peninsula, *R.W. Jobson 2703 & W.A. Cherry*, 19 Apr 2015 (NSW927150); Humpty Doo, *R.W. Jobson 3188 & P.C. Baleeiro*, 20 Apr 2016 (NSW927198); Noonamah, *R.W. Jobson 3958*, 19 Mar 2021 (NSW834736); Gunn Point Road, *R.W. Jobson 3960*, 20 Mar 2021 (NSW834738).

Distribution, Ecology & Phenology: Known from across northern WA from the west Kimberley region to Kununurra. Also widespread across the Top End of the NT (Fig. 1). Grows in wet sand or clay in seasonal swamps and near creeks. Flowers and fruit observed in February–September.

Conservation Status. Although widespread across the Kimberley and Top End regions, populations appear to be patchy, but it is also possible that the populations are highly localised. It is therefore recommended that this species be listed in WA and NT as Data Deficient, requiring further study to assess conservation status and determine potential threats.

Notes. When observed in the field the morphologically distinct *U. lasiocaulis* is unlikely to be confused with any other species (Fig. 3 c–d, 5, 6). Collections from NT tend to be more hirsute (entire indumentum) than those from WA (1/5 from near base). Taylor (1989) illustrated most of the floral forms, although those of the currently circumscribed entity are only represented by fig. 24a 1, 10 (*Taylor 17102, 17174*; habit & hairs on peduncle), and 24b 1–2 (*Taylor 17174*; dorsal view of corolla).

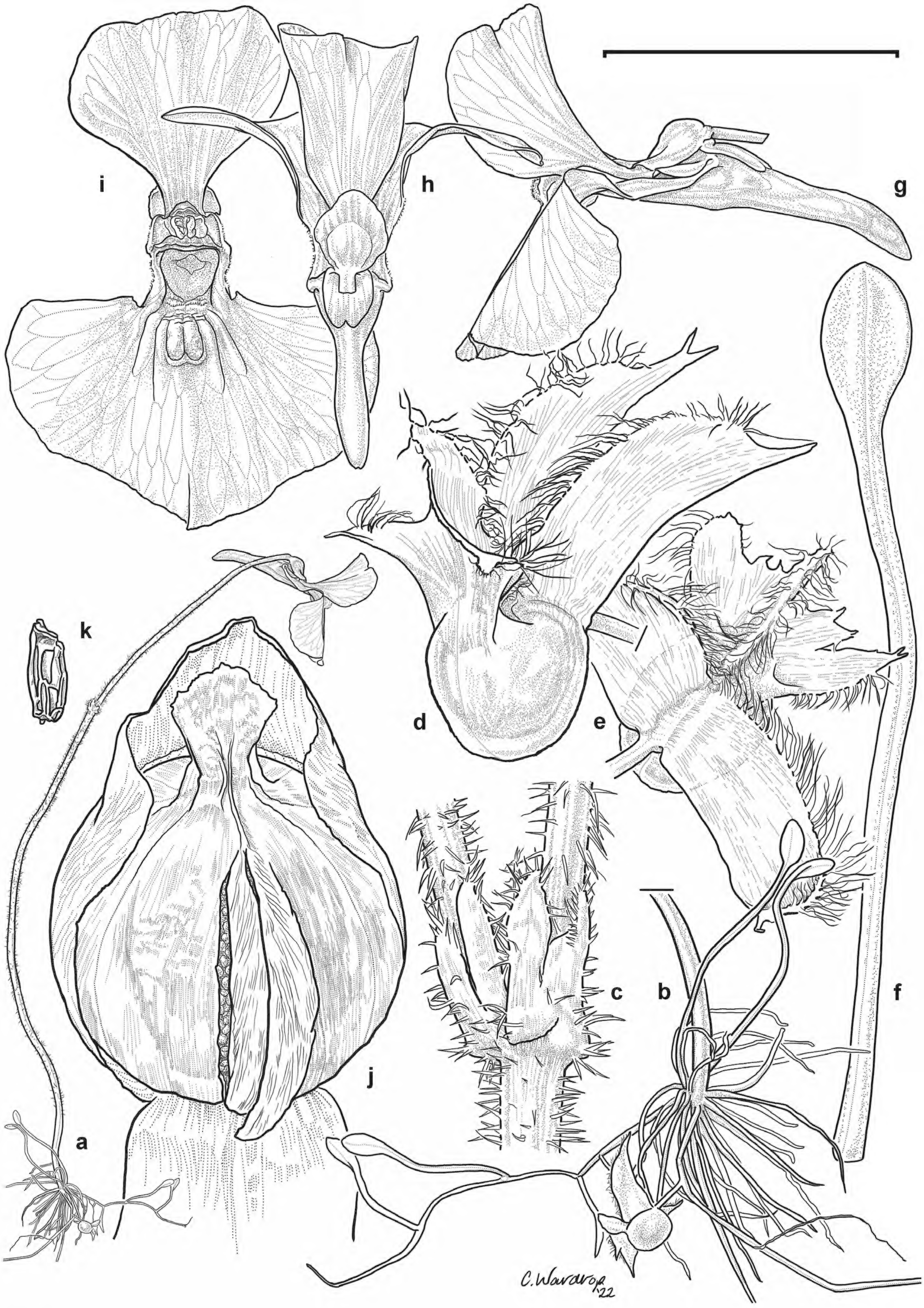

Fig. 6. *Utricularia lasiocaulis*. a, habit; b, stolon with vegetative parts and peduncle base in situ; c, bract and bracteoles; d, bladder-trap frontal view; e, bladder-trap ventral view; f, leaf adaxial surface; g, flower lateral view; h, flower dorsal view; i, flower frontal view showing stamens and ovary; j, fruit ventral view; k, seed. Scale bar: a = 33 mm; b, g–i = 10 mm; c, f = 3.3 mm; d, e & j = 3.3 mm; g–i, q = 2.5 mm; k, = 1 mm. Material used: a–j = *Jobson 2690 & Cherry* (NSW927133); k = *Jobson 3960* (NSW834738).

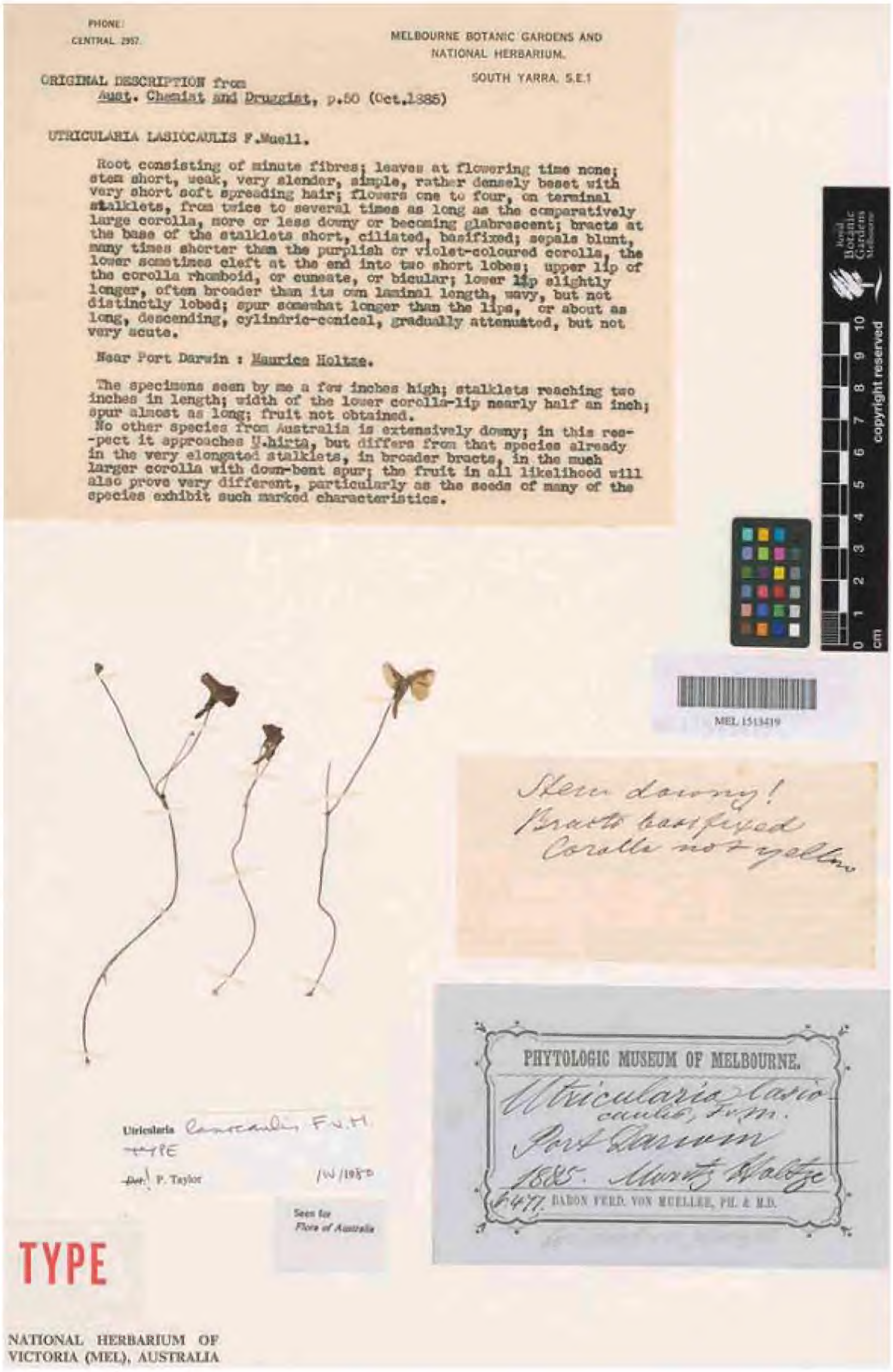

Fig. 7. Holotype of *Utricularia lasiocaulis* F.Muell. (*M. Holtze 477*; MEL 1513419)

Utricularia brennanii R.W.Jobson & Baleeiro, *sp. nov.*

Diagnosis: Similar to *U. lasiocaulis* in having two raised orange ridges at the base of the lower lip but differs in possessing ridges with claw-like apices, corolla lower lip three lobed, superior part of upper lip obovate or obcordate, and peduncle hairy on lower 1/3.

Type: AUSTRALIA: Northern Territory: Jabiru [precise location withheld], *R.W. Jobson 4019*, 27 March 2021 (holo: NSW1119364; Iso: NSW834766 – spirit, DNA).

Small to medium sized annual, terrestrial herb. *Rhizoides* capillary, simple, up to 7 mm long, 0.15 mm thick at base tapering to 0.1 mm near the apex, numerous from the peduncle base, 1 from stolon nodes. *Stolons* numerous, branched, filiform, 0.15–0.2 mm thick, internodes 3–5 mm long. *Leaves* numerous, rarely at peduncle base and 1 on stolon nodes, petiolate, lamina spathulate, 1–1.5 mm long, 0.6–1 mm wide, single nerve, apex rounded, total length up to 2–3.5 mm long. *Traps* stalked, ovoid, 0.6–1.4 mm long; 1 at nodes and on internodes; uniform, mouth lateral with a 3-lobed dorsal appendage, central lobe 0.5 mm long, two lateral lobes c. 0.2 mm long, ciliate margin, two lateral appendages 0.7 mm long with ciliate margin, ventral wings absent. *Inflorescence* solitary, 60–180 mm long; flower solitary or with two or three pedicles arising in succession; peduncle erect, solid, terete, hirsute for 1/3 from base of peduncle then glabrous, 0.3–0.4 mm thick. *Scales* absent; *Bract and bracteoles* equal, basifixed, gibbous at base, lanceolate, 1–1.2 mm long, c. 0.2 mm wide, ciliate margin around base and apex, apex rounded. *Pedicel* erect or deflexed near apex, filiform, tapering and apically 20–33 mm long. *Calyx* lobes unequal; upper lobe ovate, 1.8–2.1 mm long, 1.2–1.5 mm wide; lower lobe shorter, narrowly ovate, with apex emarginate 1–1.2 mm long, 0.7–0.8 mm wide. *Corolla* 8–14 mm long, upper side dark purple, mauve, or light violet, underside orange; *upper lip limb* constricted near the middle, 4.1–4.8 mm long, superior part obovate or obcordate with apex entire or rarely emarginate, inferior part ovate with margin ciliate; *lower lip limb*, obovate in outline with apex rounded, 4–12 mm long, 5–14 mm wide, deeply to shallowly 3-lobed; base of lower lip with two orange claw-like ridges, with 3 longer dark violet streaks either side; *spur* projecting c. 90°–110° to the lower lip, conical in cross-section at the base, subulate, tapering to an acute apex, 3.2–5.5 mm long, 1–2.1 mm wide near base, equal or slightly longer than the length of lower lip. *Capsule* globose, c. 2.1 mm in diameter, dehiscing from a longitudinal, ventral, marginally thickened slit. *Seeds* 0.3–4 mm long. *Pistil* c. 1.4 mm long; *Filaments* curved c. 1.2 mm long. *Pollen* 3-colporate. Figures 3e–f, 8.

Additional specimens examined: AUSTRALIA: Queensland: Dingo Spring, *Fensham R. 4506*, 1 Jun 2001 (BRI); Maroochy airfield, *Taylor P. 17075* (K); Near Bundaberg, *Jobson R.W. 2036*, 13 Jul 2013 (NSW922764); N of Mt Surprise, *Fensham R. 4506*, 1 Jun 2001 (BRI); Jungle Creek swamp, *Jobson R.W. 2845*, 18 Jul 2015 (NSW1056740); Unnamed swamp 8 km S of Bamaga, *Jobson R.W. 3777 & Baleeiro P.C.*, 21 Jul 2019 (NSW945287). NORTHERN TERRITORY: Flying Fox Ck, Central Arnhem Road, *Jobson R.W. 2226 & Baleeiro P.C.*, 20 Apr 2014 (NSW852283); 3.2 km E of Jabiru Aerodrome, *Jobson R.W. 4019 & Baleeiro P.C.*, 27 Mar 2021 (NSW); 10 km NE of Mount Bundey, *Jobson R.W. 2691 & Baleeiro P.C.*, 18 Apr 2015 (NSW927135), Nhulumbuy, *Brennan K. 6967*, 11 May 2006.

Etymology: The specific epithet honours Kym Brennan of the Northern Territory Herbarium (DNA). Kym has made many of the important botanical collections essential for understanding the flora of the Northern Territory, including the taxa of the *Utricularia lasiocaulis* complex.

Distribution, Ecology & Phenology: In the Northern Territory, known from the Darwin area to Arnhem Land. In Queensland, collected from the Cook region south to the Moreton region (Fig. 1). In NSW, known only from a single site in Torrington State Conservation Area, Northern Tablelands (Boaz Ng, pers. comm.). Grows in seasonally wet grassland, swampland, and heathland on sandy substrate or in seepage on sandstone or granite outcrops. Flowers all months.

Conservation Status: Although it is the most widespread species of the *Lasiocaulis* complex from across the Top End to Cape York and south to Northern Tablelands of NSW, it is often locally very patchy and infrequent. We, therefore, recommended that this species be listed in NT, Qld and NSW as Data Deficient, requiring further study to assess conservation status and determine potential threats.

Notes: Although the corolla of *U. brennanii* is quite variable in colour and shape, it can be easily differentiated from *U. disjuncta* by its dark yellow vs. white ridges at the base of the lower lip, and its corolla abaxial surface orange vs. white. Even though *U. lasiocaulis* was observed to grow near *U. brennanii* at several sites in the NT there was no evidence of hybridization, and some evidence they each occupy different microhabitats.

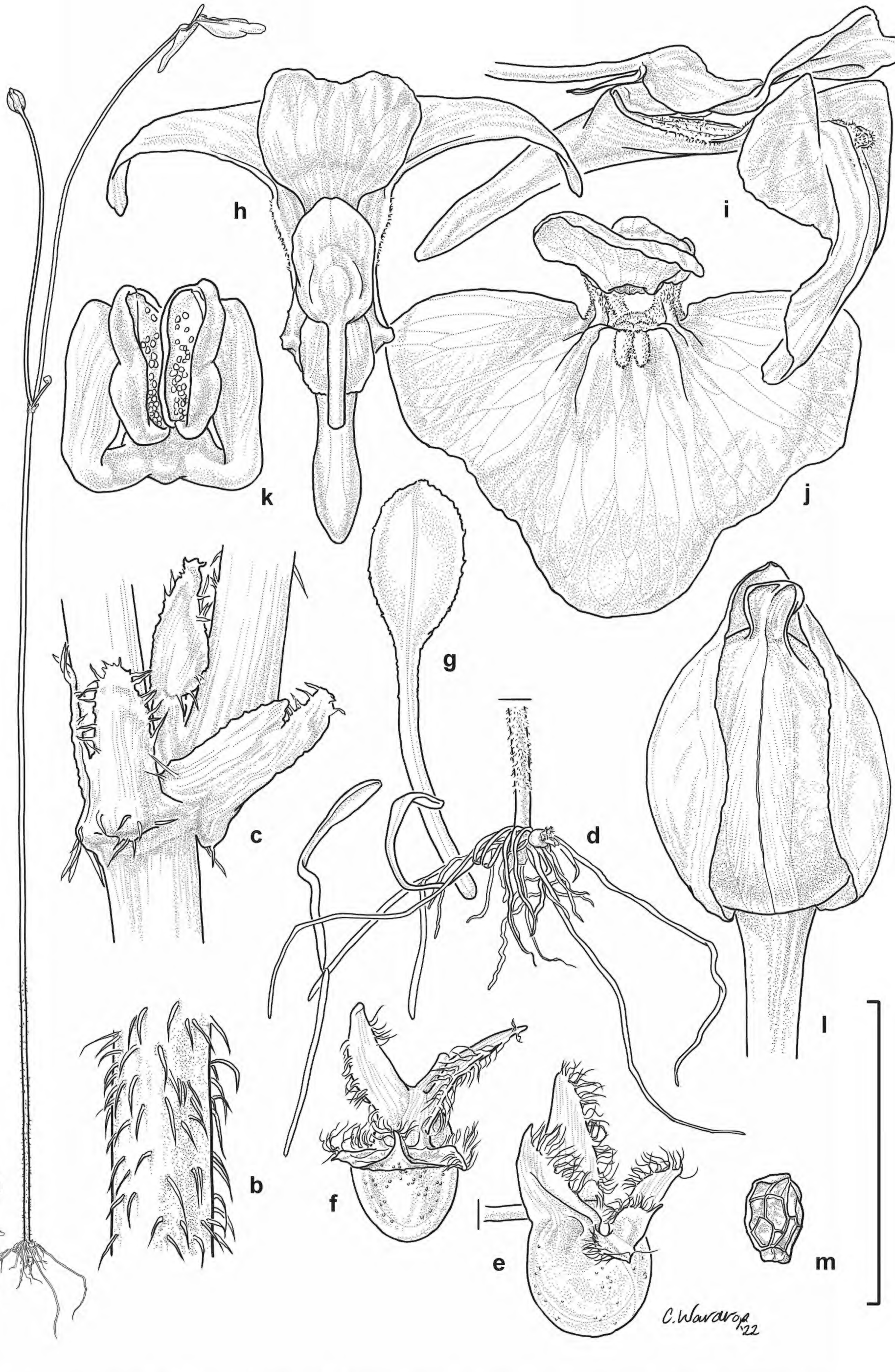

Fig. 8. *Utricularia brennanii*. a, habit; b, peduncle base; c, bract and bracteoles; d, stolon with vegetative parts and peduncle base in situ; e, bladder-trap lateral view; f, bladder-trap ventral view; g, leaf adaxial surface; h, flower dorsal view; i, flower lateral view; j, flower frontal view; k, stamens frontal view; l, fruit ventral view; m, seed. Scale bar: a = 33.3 mm; b, c, k = 1.6 mm; d = 10 mm; e, f = 2 mm; g = 3.3 mm; h-j = 7.1 mm; l = 2.5 mm; m = 1 mm. Material used: a-g, k, l = *Jobson 4019 & Baleeiro* (NSW834766 – spirit & sheet); h-j = *Jobson 4022 & Baleeiro* (NSW962501 – spirit); m = *Jobson 3777 & Baleeiro* (NSW945287 – spirit)

Utricularia cowiei R.W.Jobson & Baleeiro, *sp. nov*.

Diagnosis: Similar to *U. lasiocaulis* in having peduncle hairy near the base but differs in having a deep purple vs. light mauve corolla with no orange tinge on the under surface, two raised white vs. yellow ridges at base of lower lip, and lower corolla lip deeply three lobed vs. margin entire.

Type: WESTERN AUSTRALIA: North Kimberley: King Edward River [precise location withheld], *Dunlop C.R. 5366*, 29 February 1980 (holo: DNA D0016726, iso: DNA, PERTH, MEL, K – all spirit).

Small to medium sized annual, terrestrial herb. *Rhizoides* capillary, simple, up to 4 mm long, 0.15 mm thick at base tapering to 0.05 mm near the apex, numerous from the peduncle base, 1 or 2 from stolon nodes. *Stolons* few, branched, filiform, 0.15–0. 2 mm thick, internodes 2–3 mm long. *Leaves* numerous, few at peduncle base and 1–2 on stolon nodes, petiolate, lamina spatulate, 1.2–2 mm long, 0.5–1.0 mm wide, single nerve, apex rounded, total length up to 3.7 mm long. *Traps* stalked, ovoid, 0.9–1.5 mm long; 1 or 2 at base of peduncle, and on internodes; uniform, mouth lateral with a simple dorsal appendage c. 0.1 mm long, and two lateral appendages c. 0.1 mm long, ventral wings with scattered course hairs on margin. *Inflorescence* solitary, 70–120 mm long; flower solitary or rarely with two or three pedicles arising in succession; peduncle erect, solid, terete, hirsute for 1/5 from base of peduncle then glabrous, 0.35–0.4 mm thick. *Scales* absent; *Bract and bracteoles* equal, basifixed, slightly gibbous at base, ovate, 0.8–1.0 mm long, c. 0.3 mm wide, ciliate on margin and course hairs scattered on upper surface, apex rounded or acute. *Pedicel* erect, filiform, tapering apically, 15–60 mm long. *Calyx* lobes unequal; upper lobe ovate, 1.9–2.1 mm long, 1.5–1.6 mm wide; lower lobe shorter, oblong with apex bifid, 1.5–1.6 mm long, 1.3–1.4 mm wide. *Corolla* 7–11 mm long, upper side violet, underside light violet with white spur; *upper lip limb* constricted below the middle where bent upwards at c. 90°, 5.5–7.5 mm long, 4.1–5.0 mm wide, superior part broadly obovate with apex truncate or slightly bilobed, inferior part ovate with margin ciliate; *lower lip limb*, transversely elliptic in outline with apex rounded, 7–9 mm long, 11–13 mm wide, deeply 3-lobed, base of lower lip with two white, prominently raised ridges, with 2 longer dark violet rimmed white streaks either side; *spur* usually projecting c. 90° to the lower lip, conical in cross-section at the base, tapering then slightly bulbous towards apex, 4.8–5.2 mm long, c. 1.4 mm wide near middle, shorter than the length of lower lip. *Capsule* globose, c. 2.2 mm in diameter, dehiscing from a longitudinal, ventral, marginally thickened slit. *Seeds* obovoid, 0.25–0.45 mm long. *Pistil* c. 1.5 mm long; *Filaments* curved c. 1.0 mm long. *Pollen* 3-colporate. Figures 3g–h, 9.

Additional specimens: AUSTRALIA: Western Australia: North Kimberley: King Edward River, *Jobson R.W. 2658 & Cherry W.*, 14 Apr 2015 (NSW 924822 - spirit); Harding Range, *Barrett M.D. 2775*, 25 Mar 2010 (PERTH); Theda Station, *Jobson R.W. 2668 & Cherry W.*, 16 Apr 2015 (NSW 909477).

Etymology: The specific epithet honours Dr Ian Cowie, former (retired) Chief Botanist of the Northern Territory Herbarium (DNA), who has made many important collections and provided essential information for understanding the taxonomy of Australian *Utricularia*.

Distribution, Ecology & Phenology: Known from three sites in the north Kimberley region of Western Australia (Fig. 1); King Edward River area of Mitchell Plateau, c. 90 km to the east on Theda Station and c. 250 km to the SW in the Harding Range. Found in seasonally wet grassland on sandstone pavement in sandy substrate with fine grasses and sedges. Collected in Flower in February and April.

Conservation status: Although only know from four collections at three sites, the disjunction between the sites suggests it is likely to have a broader distribution across north Kimberley. We recommend that this species is Data Deficient, requiring further study to assess distribution and conservation status and determine potential threats.

Notes: The deeply three-lobed corolla of *U. cowiei* is similar to the Kimberley endemics *U. tridactyla* P.Taylor and *U. papilliscapa* R.W.Jobson & M.D.Barrett but in both latter cases the ridges at the base of the corolla lower lip are yellow vs. white, and the base of the peduncle is papillose vs. hirsute.

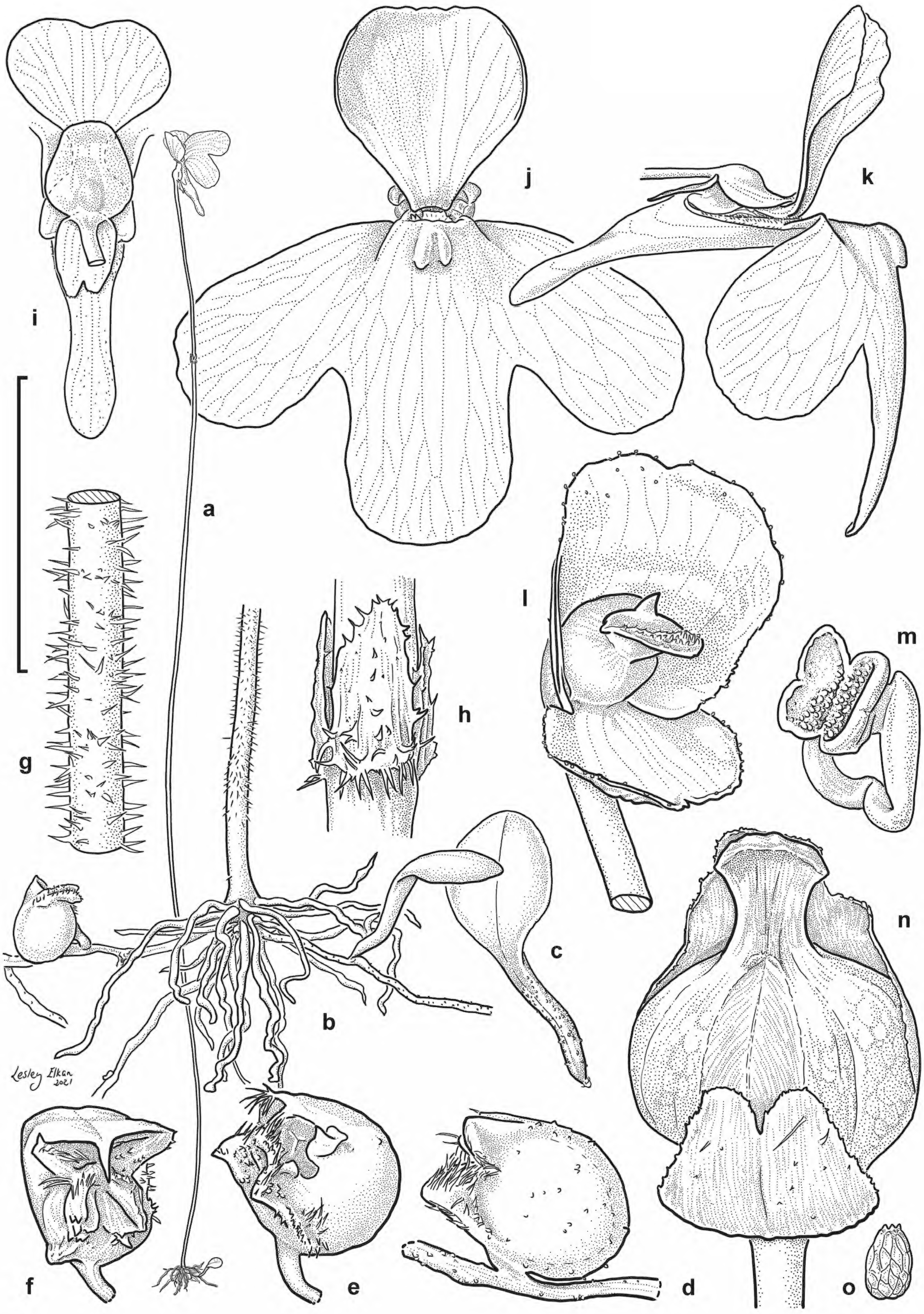

Fig. 9. *Utricularia cowie*. a, habit; b, stolon with vegetative parts and peduncle base in situ; c, leaf adaxial surface; d, bladder-trap lateral view; e, bladder-trap ¾ frontal view; f, bladder-trap ventral view; g, peduncle base; h, bract and bracteoles; i, flower dorsal view; j, flower frontal view; k, flower lateral view; l, calyx with ovary; m, stamen lateral view; n, fruit ventral view; o, seed. Scale bar: a = 33.3 mm; b = 5 mm; c = 3.3 mm; d–f, h, l & n = 2 mm; g & m = 1.7 mm; i-k, = 7 mm; o = 1 mm. Material used: *Jobson 2658 & Cherry* (NSW924822 - spirit).

Utricularia disjuncta R.W.Jobson & Baleeiro, *sp. nov*.

Diagnosis: Similar to *U. leptorhyncha* in having corolla lower lip three-lobed with lower surface and whole upper lip white but differs in having long lanceolate vs. short broad bladder-trap ventral wings, a violet vs. light mauve corolla, single strongly raised white ridge with bifurcating apex vs. two slightly raised ridges at the base of the lower lip, and lower corolla lip broadly transversely elliptic vs. flabellate in outline; upper lip emarginate vs. bilobed.

Type: AUSTRALIA: Northern Territory: Howard River Floodplain, Gunn Point Rd. [precise location withheld], *R.W. Jobson 3962*, 20 March 2021 (holo: NSW1119360, iso: DNA, NSW834742 – spirit).

Small to medium sized annual, terrestrial herb. *Rhizoids* capillary, simple, up to 6 mm long, 0.2 mm thick at base tapering to 0.1 mm near the apex, numerous from peduncle base, 2–3 from the stolon nodes. *Stolons* few, c. 12 mm long, branched. *Leaves* few, 1 on stolon nodes, petiolate, lamina obovate or spatulate, 1–2.5 mm long, c. 0.5 mm wide, single nerve, apex rounded, total length up to 2–10.5 mm long. *Traps* stalked, ovoid, 0.6–1.0 mm long; few on internodes; uniform, mouth lateral with a 3-parted rostrum-like dorsal appendage 0.9–1.1 mm long, and two longer, lanceolate ventral wings c. 1.9–2.1 mm long with ciliate margin. *Inflorescence* solitary, 60–150 mm long; flowers solitary or with two pedicles; peduncle erect, solid, terete, hirsute for 1/3 from base of peduncle then glabrous, 0.2–0.3 mm thick. *Pedicel* erect or deflexed near apex, filiform, tapering and dorsiventrally compressed near apex 10–32 mm long. *Scales* absent; *Bract and bracteoles* unequal, basifixed, slightly gibbous at base, narrowly ovate, bracts 1–1.2 mm long, c. 0.2 mm wide, bracteoles c. 0.7 mm long, ciliate margin, apex acute. *Calyx* lobes unequal; upper lobe ovate, 1.1–1.5 mm long, 0.8–1 mm wide; lower lobe shorter, narrowly ovate, with apex truncate or bifid 1–1.2 mm long, 0.4–0.6 mm wide. *Corolla* 10–14 mm long, upper side of lower lip light violet, underside white; *upper lip limb* white, constricted near the middle, 3.2–4.5 mm long, 1.9–2.2 mm wide, superior part obovate with apex bilobed or emarginate, inferior part ovate with margin glabrous; *lower lip limb*, broadly transversely elliptic in outline with apex rounded, 3.2–8 mm long, 3.4–9 mm wide, deeply 3-lobed; base of lower lip with raised white or light yellow claw-like ridge with shortly bifurcating apex; with 2 longer white streaks with dark violet margin either side; *spur* projecting c. 90° to the lower lip, conical in cross-section at the base, subulate, tapering to an acute apex, 3.9–5 mm long, 0.9–1.2 mm wide near base, slightly shorter or equal the length of lower lip. *Capsule* globose, c. 1.8 mm in diameter, dehiscing from a longitudinal, ventral, marginally thickened slit. *Seeds* cylindrical, 0.7–0.9 mm long. *Pistil* c. 1.0 mm long; *Filaments* curved c. 1.0 mm long. *Pollen* 3-colporate. Figures 3i–j, 10.

Additional specimens: AUSTRALIA: Northern Territory: Girraween road, Darwin, *Harwood R.K. 1046*, 7 Mar 2001 (DNA); Howard River Floodplain, E side at Gunn Point Rd., *Cowie I.D. 9061*, 11 Mar 2001; Bathurst Island, *Cowie 9063 I.D. & Brennan K.G.*, 12 Mar 2001 (DNA); Noonamah, Jenkins road, *Murfet D.E. 5641 & Lowrie, A.*, 9 Mar 2007 (AD); Jabiru, *Jobson R.W. 2208*, 19 Apr 2014 (NSW852220); Bing Bong, *Jobson R.W. 3438*, 20 May 2017 (NSW934856); SE of Girraween and Anglesey Rd junction, *Jobson R.W. 3965*, 20 March 2021 (NSW834744).

Etymology: The specific epithet *disjuncta* refers to the sporadic geographic distribution of the known locally restricted populations.

Distribution, Ecology & Phenology: Known from several sites on the Howard River Floodplain near Darwin, Bathurst Island, and a single known collection (*Jobson 3438)* from Bing Bong in the Gulf region of the Northern Territory. Grows in seasonally wet grassland and woodland on sandy substrate. Collected in flower from March and May.

Conservation status: Although only known from few collections from near Darwin, Bathurst Island, and Bing Bong in the Gulf region, the disjunction between these sites suggests it is likely to have a broader distribution across the Top End, NT. At these sites it was observed to be locally infrequent which may indicate that it has often been overlooked during surveys. We recommend that this species be considered Data Deficient, requiring further study to assess distribution and conservation status and determine potential threats.

Notes: The molecular phylogeny (Fig. 2) shows a sister relationship between *U. disjuncta* and *U. brennanii*, although these two are unlikely to be confused in the field (see *U. brennanii* notes above for differences). It instead resembles most closely *U. leptorhyncha* in having the corolla lower-surface and upper-lip white. Despite this similarity, these two species can be easily differentiated by the smaller size of the *U. leptorhyncha* corolla 5–7 mm vs. 10–14 mm long, and bladder trap appendages non-ciliate vs. ciliate.

Fig. 10. *Utricularia disjuncta*. a, habit; b, stolon with vegetative parts and peduncle base in situ; c, peduncle base; d, leaf adaxial surface; e, bract and bracteoles; f, flower frontal view; g, flower lateral view; h, flower dorsal view; i, stamens frontal view; j, bladder-trap frontal view; k, bladder-trap ¾ rear view; l, bladder-trap rear view; m, fruit ventral view; n, seed (immature). Scale bar: a = 33.3 mm; b = 10 mm; c = 3.3 mm; c, e, i = 2 mm; g & m = 1.6 mm; d, = 3.3 mm; f-h = 7.1 mm; j-m = 2 mm; n = 1 mm. Material used: = *Jobson 3962 & Baleeiro* (NSW834742 & spirit).

Key to species of the *U. lasiocaulis* complex and allied species (sect. *Lasiocaules*).

(Abbreviations: N.T. = Northern Territory; Qld = Queensland; W.A. = Western Australia)

1a. Corolla white or pink; bract and bracteole basisolute ..... ***U. kamienskii*** (N.T.)

1b. Corolla light mauve to purple; bract and bracteole basifixed 2

2a. Corolla lower lip spur apex acute; bladder trap appendages non-ciliate ..... ***U. leptorhyncha*** (N.T.)

2b. Corolla lower lip spur apex usually rounded; bladder trap appendages ciliate 3

3a. Peduncle densely hirsute usually along 1/5 to entire length; underside of the lower lip of corolla orange to dark orange ..... ***U. lasiocaulis*** (N.T., W.A.)

3b. Peduncle pubescent/hirsute from near the base up from 1/6 to 1/4 of total length; underside of lower lip of corolla white, light purple or light orange 4

4a. Lower corolla lip deeply three-lobed; bladder-trap ventral wings shorter than the bladder-body ..... ***U. cowiei*** (W.A.)

4b. Lower corolla lip entire or shallowly three lobed; bladder-trap ventral wings longer than the bladder-body 5

5a. Underside of corolla lower lip light orange, upper lip mauve or purple..... ***U. brennanii*** (N.T., Qld)

5b. Underside of corolla lower lip white, upper lip white ..... ***U. disjuncta*** (N.T.)

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Caloglossa fluviatilis (Delesseriaceae, Rhodophyta) from Bataan province, Luzon Island, Philippines, a new country record

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Abstract

Caloglossa fluviatilis Krayesky, Fredericq & J.N.Norris is one of the least known freshwater algal species of its genus. It has been reported thus far from its type locality in Pedro Miguel, Republic of Panama, and Chalakkudy and Periyar Rivers in the State of Kerala, India. This study presents a new locality record of the species from Bataan province on the island of Luzon, Philippines. *Caloglossa fluviatilis* is characterised by having (1) a blade-like internodal region that is <1.0 mm, (2) moderate development of adventitious secondary branches at the node, and (3) fewer than eight rhizoidal filaments arising from pericentral cells at the node. Indeed, this Philippine population of *C. fluviatilis* has helped fill the gaps and extended the distribution of the species to the western Pacific region. Further studies and reassessment of freshwater *Caloglossa* specimens will contribute to further understanding of species of this little-known genus.

Introduction

The Ceramiales is one of the eight orders in the class Florideophyceae of the phylum Rhodophyta with a handful of freshwater species (Vis and Necchi, 2021). One of its members, the genus *Caloglossa* (Harvey) G.Martens (Delesseriaceae, Ceramiales), is widespread in tropical to temperate mangrove, estuarine, and freshwater habitats. The genus comprises 22 currently accepted species (Guiry, 2022), and about six species have been documented in permanent freshwater streams. However, despite its widespread distribution, few morphological variations have been reported among its species, and some are occasionally difficult to distinguish morphologically. Recent phylogenetic analyses within *Caloglossa* re-examined its infraspecific classifications using molecular data and revealed some paraphyletic members (Kamiya et al., 2003; Kamiya and West, 2014; Kamiya et al., 2016; Freshwater et al., 2021). These studies successfully established the differences among *Caloglossa beccarii* (Zanardini) De Toni, *C. fluviatilis* Krayesky, Fredericq & J.N.Norris, *C. ogasawaraensis* Okamura and *C. stipitata* Post using various morphological characteristics and molecular data and led to the recognition of three new species, *C. fonticola* Fang, Nan, Feng, Liu, Liu & Xie; *C. kamiyana*

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Freshwater, Cath.E.Miller & Frankovich, and *C. manaticola* Freshwater, Cath.E.Miller & Frankovich (Fang et al., 2021; Freshwater et al., 2021).

About six taxa of the genus *Caloglossa* have been described and documented in countries in Southeast Asia (Kamiya et al., 2003; Johnston et al., 2014; Kamiya and West, 2014; Kamiya et al., 2016; Chankaew et al., 2019). There have only been two reported *Caloglossa* in the Philippines, *C. ogasawaraensis* and *C. stipitata* (Kamiya and West, 2014; Kamiya et al., 2016). The former is generally a brackish water species but was reported in Taal Lake, a freshwater lake on the island of Luzon, purportedly a marine area previously connected to the nearby Balayan Bay until in 1754 when a series of volcanic eruptions constricted its connection to the sea and diverted Pansipit River, its only outlet to the sea, hence increasing the lake surface level to its current elevation which is 3 m above sea level (Hargrove, 1991; Willette et al., 2014). For both species, however, no voucher specimens were deposited in local herbaria, nor was any information or description available in the country. The insufficient knowledge of freshwater red algae in the Philippines is likely a product of several factors, including insufficient sampling efforts caused by inadequate interest and the lack of suitable habitats. Alteration of waterways, such as regime shifts, construction of dams, dredging, and environmental pollution, such as sewage disposal in natural freshwater bodies, can further reduce the occurrence of these algae.

A population of the freshwater red algae, *Caloglossa*, was collected from a forested stream in the Bataan province of Luzon Island, Philippines. The identity of the species is presented in this paper using its morphological characteristics as evidence.

Materials and Methods

The specimens were collected on 06 June 2022 from the upper section of Mauban Creek, at 14°39'01.49"N, 120°19'05.06"E, near a waterfall in Barangay Nagbalayong, Municipality of Morong, Province of Bataan, on the island of Luzon, Philippines. The site is within a deep ravine at 67 m asl, surrounded by disturbed tropical lowland rainforest with a heavy litter layer on the forest floor. Portions of the specimens collected were preserved in 70% ethanol for identification and morphological characterisation. The remaining portions were dried for herbarium specimens as vouchers deposited in the herbaria of the University of the Philippines Los Baños (CAHUP) and the National Museum of the Philippines (PNH).

Samples of the collected materials were washed in tap water for a few minutes and mounted with 50% sugar syrup in distilled water with 10% formalin to highlight cytoplasmic content. These materials were examined under Amscope 20–80× Compact Multi-Lens Stereo Microscope and Harman XSZ-107BN Binocular Microscope and photographed using Amscope MU500 5MP USB Microscope Camera. Species identification was based on two collections. Species were determined using diagnostic morphological characters consulted from references (Krayesky et al., 2012; Kamiya et al., 2016).

Results

Specimens were identified as *Caloglossa fluviatilis* Krayesky, Fredericq & J.N.Norris (Delesseriaceae, Rhodophyta), which is new to the freshwater algal flora of the Philippines and represents the first report of the species in Southeast Asia. Worth mentioning is that this new record represents an expansion of its current geographical range, which was previously known only from its type locality in Pedro Miguel, Republic of Panama, and in Kerala state, India.

Caloglossa fluviatilis Krayesky, Fredericq & J.N.Norris, *Phycologia* 51(5): 523–525, figs 14–15 (2012).

Type: REPUBLIC OF PANAMA: Pedro Miguel, Pedro Miguel Lock, [08°59'46.42"N, 79°35'30.49"W], on the cement of western wall of upper western lock (freshwater), 5 May 1999, *B.S. Wysor 421* (holo: U.S. Alg. Type Coll. 217746; iso: LAF).

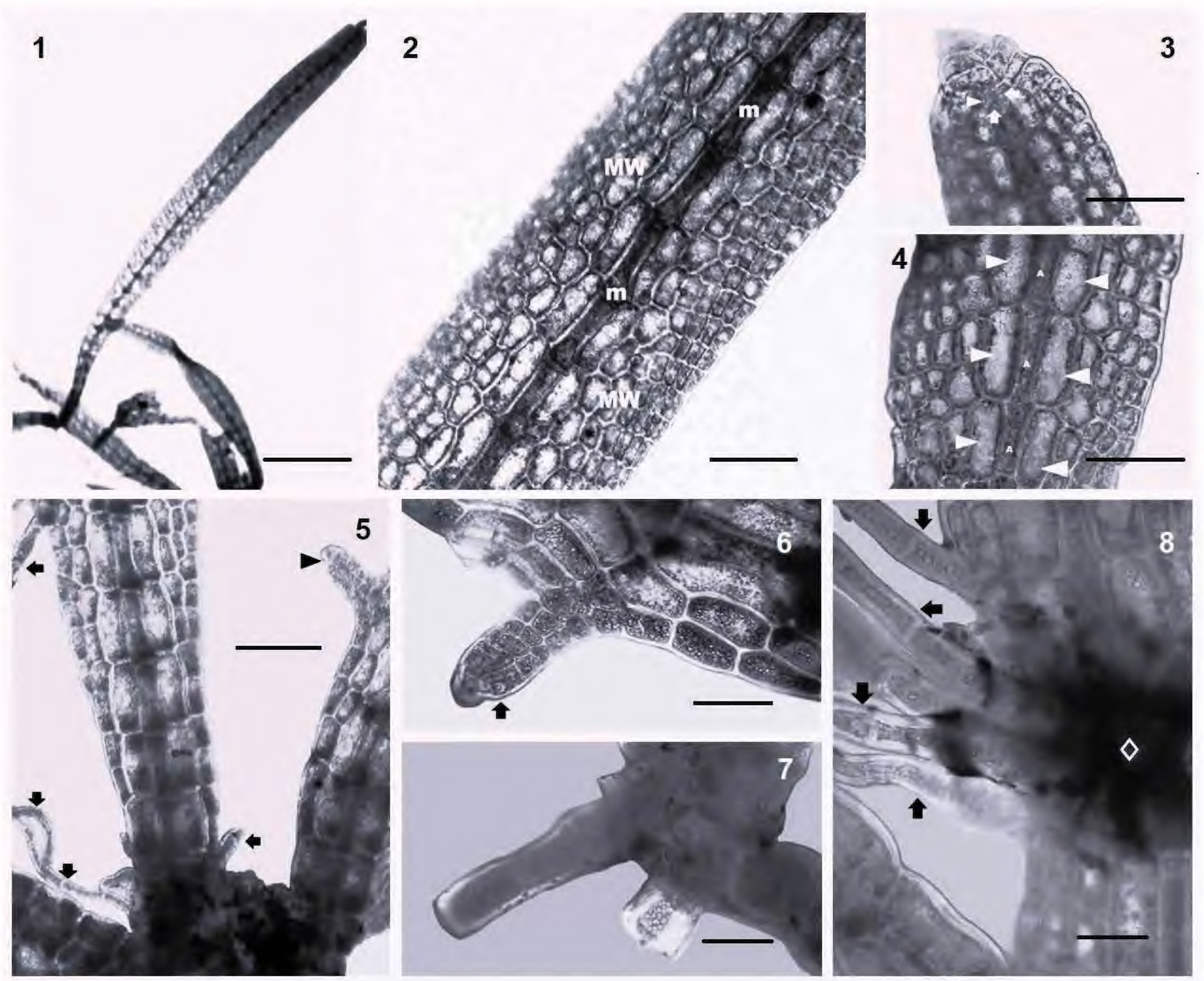
Thalli densely tufted, laminate, reddish to pale violet red, subdichotomously branching up to (0.5–)0.6–1.4 cm long, consisting of a midrib region with monostromatic wings on either side. The midrib region comprises two transverse and two lateral periaxial cells and one axial cell series. Blades narrowly lanceolate up to 2.0–6.0(–10.0) mm long and 0.7–1.2 mm wide at the median node region, becoming strongly constricted at nodes. Endogenous branching is absent. Adventitious branching is present. Both rhizoids and adjacent marginal wing cells are formed from the nodal periaxial cells. Basal rhizoidal cells are not tightly adherent to develop into a stipe-like cortical pad. Adaxial cell row derived from the first axial cell of the lateral axis is present. One cell row is derived from the nodal axial cell opposite the lateral branch, whereas two to four cell

rows are derived from the first axial cell of the main axis opposite the lateral branch. Reproductive structures not seen. (Figs 1–8)

Specimens examined: PHILIPPINES: Mauban Creek, Barangay Nagbalayong, Municipality of Morong, Province of Bataan, Luzon Island, freshwater stream, heavy shade, complex mixed rocky and muddy bottom, disturbed tropical lowland rain forest, 67 m asl, 14°39'01.49"N, 120°19'05.06"E, 06 June 2022, *V.C. Linis & L.V. Vitug 5731-22* (CAHUP; PNH); *loc. cit.*, 06 June. 2022, *V.C. Linis & L.V. Vitug 5732-22* (CAHUP; PNH).

Habitat: This population of *C. fluviatilis* was found in a single locality in Mauban Creek, Municipality of Morong, on the island of Luzon, Philippines, submerged in a forest stream with cool, clear flowing water, heavily shaded by the forest canopy above. The plant grew on rocks and cobbles on the stream bottom mixed with muddy sediments. The stream is in a shallow ravine surrounded by disturbed tropical lowland rainforest with several fallen tree trunks scattered along its banks.

Distribution: The species was only known from the type locality – Pedro Miguel, Republic of Panama; and Chalakkudy and Periyar Rivers in the State of Kerala, India; and now in Mauban Creek, Bataan Province, Luzon Island in the Philippines (a new record for Southeast Asia).



Figs. 1–8. Vegetative thalli of *Caloglossa fluviatilis* Krayesky, Fredericq & J.N.Norris. **1.** Habit. **2.** Internodal blade showing the midrib (m) and the monostromatic regions (MW). **3.** Apex and distal node of the thallus. The vertical arrow points to the nodal axial cell. The horizontal arrow points to the first axial cell of the developing lateral axis. The arrowhead points to the first cell of the main axis. **4.** Mature internodal blade showing the nodal axial cell (A). Six arrowheads point to the periaxial cells. **5.** Thallus blade showing strong constriction at the node. Four arrows pointing to rhizoidal filaments. The arrowhead points to a juvenile adventitious branch. **6.** Higher magnification of the thallus internodal blade margin. A vertical arrow points to a juvenile adventitious branch. **7.** Rhizoidal nodes displaying the type F arrangement of Kamiya et al. (2003). Mound of cortical cells at the bases of rhizoidal filaments is absent. **8.** Rhizoidal filaments (arrows) produced at the node. The nodal cell (diamond) is visible. All from *V.C. Linis & L.V. Vitug 5731-22* (CAHUP). Scale bars: **1** = 2 mm; **2–4** = 100 μm; **5–8** = 50 μm.

Etymology: The species epithet *fluviatilis* (from the Latin 'of the stream') refers to the freshwater habitats where this species was initially collected.

Taxonomic notes: The genus *Caloglossa* is recognised by possessing (1) flat-dichotomously branched reddish blades with constrictions, (2) monostromatic blades at least at the outer portion composed of oblique series of hexagonal cells, (3) a prominent midrib composed of a broad axial row of cells surrounded by a cortex of elongated cells, and (4) rhizoids arising at constrictions, either from the midrib area or from the peripheral layer of cells (Sheath, 2003). This algal sample collected from Luzon Island, Philippines, also fits most closely the description of *Caloglossa fluviatilis*. Apart from being exclusively distributed in freshwater habitats, *C. fluviatilis* is distinctive in having (1) a thallus width at the internode region narrower than 1.0 mm, (2) moderate development of adventitious secondary branches at the node, and (3) fewer than eight rhizoidal filaments deriving from pericentral cells at the node (Kamiya et al., 2016).

Caloglossa fluviatilis can also easily be distinguished from *C. ogasawaraensis* in that the latter possesses "type E" rhizoid arrangements, which are produced on the ventral side of nodes with a single rhizoid originating from ventral and lateral pericentral cells of the node and those immediately above and below it, whereas *C. fluviatilis* has "type F" rhizoids, which are produced on the ventral side of nodes with mostly single, but sometimes multiple, rhizoids originating from nodal periaxial and adjacent marginal wing cells (Kamiya et al. 2003). In addition, *C. fluviatilis* has a median thallus blade up to 0.1–0.5 mm wide, a smaller range that does not overlap with that of *C. fluviatilis* (0.8–1.1 mm). Unlike *C. fluviatilis*, *C. ogasawaraensis* is not strongly constricted at the nodes.

Recently, a new *Caloglossa* species, *C. fonticola* Fang, Nan, Feng, Liu, Liu & Xie, has been documented from an underground spring in Bama County, Guangxi, China (Fang et al., 2021). *C. fonticola*, however, is morphologically distinguishable from *C. fluviatilis* and other *Caloglossa* species by a unique combination of character states, including (1) the possession of linear thallus internodal blades which are hardly or only slightly constricted at nodes, (2) absence of adventitious branches and endogenous branches, and (3) formation of unicellular rhizoids from clusters of wing cells arising from the first three axial cells of the main axis and lateral axis.

Proposed IUCN Conservation Assessment: Due to scant information regarding its geographic range, habitat, or habitat range, being known only in several localities globally, the algal collections presented herein satisfy criteria B2 and D of the IUCN Red List (IUCN Standards and Petitions Committee, 2019). Therefore, we propose considering *C. fluviatilis* as Critically Endangered (C.R.) in terms of its conservation status following Fernando et al. (2008).

In the Philippines, *C. fluviatilis* has a small population size (<50 mature individuals), and it is restricted to a single, small area on Luzon Island, relatively close to a human settlement. The population can be severely reduced or driven to extinction if not managed well due to habitat destruction or modification.

Discussion

The specimens collected from the Philippines have extended the distributional range of *C. fluviatilis*, previously recorded from its type locality – Pedro Miguel, Republic of Panama, and in Chalakkudy and Periyar Rivers in the State of Kerala, India. Interestingly, the collection locality of the Philippine specimens is about 16,600 km away from the species' type locality and about 4,950 km away from the State of Kerala in India, filling a gap in records and extending the distribution of *C. fluviatilis* to the western Pacific region.

These Philippine collections represent only the third report of *C. fluviatilis* worldwide. Its discovery in the Philippines has reinforced our suspicion that this species could be more widely distributed in freshwater habitats. Careful reassessment is needed for freshwater *Caloglossa* specimens like those we have presented in this study. A dichotomous key is provided here to highlight the diagnostic features amongst all species of *Caloglossa* documented in the Philippines.

Key to the species of *Caloglossa* reported in the Philippines

1. Thallus width at the internode more than 1.0 mm in width; eight or more rhizoidal filaments derived from pericentral and wing cells at the node ..... **C. stipitata**

1: Thallus width at the internode region less than 1.0 mm in width; usually fewer than eight rhizoidal filaments derived from pericentral cells at the node 2

2. Thallus blades strap-like and thallus nodes slightly constricted; more significant development of adventitious secondary branches at the node, giving an appearance of pinnate branching..... **C. ogasawaraensis**

2: Thallus blades lanceolate and thallus nodes strongly constricted; moderate development of adventitious secondary branches at the node..... **C. fluviatilis**

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Taxonomy and ecology of *Sphagnum*-associated Desmids from the New England Tablelands, New South Wales, Australia

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Abstract

Desmids associated with *Sphagnum* L. from terrestrial and aquatic habitats were investigated in the New England Tableland Bioregion. Descriptions and figures for 80 taxa are presented herein, nine of which are newly recorded for Australia, and a further seven are newly recorded for New South Wales. Two novel species of desmid, *Micrasterias bicoronata* A.Kenins and *Cosmarium phymatodeum* A.Kenins, are described. The floristic composition of desmids at Basket Swamp and Ebor Common, were compared to assess their conservation value based on an existing and modified scheme better suited to desmids from Australia. Basket Swamp received a relatively high score based on greater species richness and numerous endemics present. In contrast, Ebor Common scored lower due to less diversity and few regionally endemic species. This study also highlights that the desmid community found amongst *Sphagnum* in Australia is highly diverse (β_{SOR} = 0.82) and can differ markedly among the four assessed sites due to spatial turnover (β_{RATIO} = 0.15). While there are species in common with the much more extensively studied *Sphagnum* habitats in central and western Europe, Australia has its own distinctive desmid floral elements.

Introduction

Desmid is a colloquial term referring to microscopic, green algae capable of asexual (via cellular division) and sexual (via conjugation between two, separate cells resulting in a zygospore) reproduction that inhabit a vast array of terrestrial and aquatic freshwater environs worldwide (Brook 1981). Traditional taxonomies separate desmids into two groups; i.e., the saccoderms and placoderms. The saccoderms exhibit cylindrical or fusiform cell outlines, simple chloroplast structure and a cell wall lacking visible pores under light microscopy (Brook 1981). Placoderm desmids, Desmidiales (Gonatozygaceae, Peniaceae, Closteriaceae and Desmidiaceae), have a much more complex cell wall architecture and cellular morphology than the saccoderms. Members of the Desmidiaceae are also by far the most morphologically diverse family in the group and include most species from the Desmidiales (Brook 1981; Coesel & Meesters 2007). However, phylogenetic reconstruction of select saccoderm and placoderm taxa from the Desmidiales and Mesotaeniaceae has recovered the placoderms (Desmidiales) as monophyletic whereas saccoderms (Mesotaeniaceae) are not, with some species more closely related to uniseriate filamentous members of the Zygnematales; such as *Mougeotia* C.Agardh and *Zygnema*

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C.Agardh (Gontcharov 2008). Although some representatives of the saccoderms can be no longer considered 'desmids', they do share similar habitats to desmids (acidic, humid and terrestrial), which have been largely understudied in Australia. Therefore, to exclude them on the basis of no longer being related to desmids would limit our understanding of their biodiversity in Australia. Apart from their understudied habitats, another reason for the limited knowledge of saccoderms in Australia is the requirement for living specimens to be observed with their chloroplasts well-preserved for reliable identification, since standard preservation usually denatures the chloroplast making certain identification extremely difficult (Coesel & Meesters 2007). Molecular investigations have also confirmed that the species-rich desmid genera *Cosmarium* Corda ex Ralfs, *Euastrum* Ehrenberg ex Ralfs, *Xanthidium* Ehrenberg ex Ralfs and *Staurastrum* Meyen ex Ralfs are polyphyletic (Gontcharov 2008; Gontcharov & Melkonian 2011). Yet, no new generic concept or revision of the group has been proposed, and as such we use the term 'desmid' in the traditional sense.

The majority of publications concerning desmids from New South Wales are from the early twentieth century by Playfair (1907, 1908, 1910, 1913, 1914, 1915, 1917; and see Skinner 2022) and were based on collections predominantly from the 'coastal' Lismore and Sydney districts. Since then, additional publications from this state have been sporadic, with contributions by Thomasson (1973), Skinner (1977, 1979) and Dingley (1995, 2001, 2002, 2004) that have generally been undertaken further inland. Skinner (1977, 1979) targeted areas of *Sphagnum* in the New England Tablelands bioregion; the focus of the present study.

Australian *Sphagnum* L. moss is primarily confined to montane and alpine regions, generally above 800 m elevation, in poorly drained, relatively infertile sites with water that is acidic and nutrient-poor. In contrast to European bogs, the Australian counterparts are often dominated by sclerophyllous shrubs, with *Sphagnum* not always the dominant component of the vegetation (Whinham & Chilcot 2002; Hunter & Bell 2007). *Sphagnum* communities in Australia are under threat from a range of stressors including grazing and trampling from cattle and feral animals (pigs, horses and deer), weed incursion, and anthropogenic disturbances (4WDing, skiing, moss poaching, draining, fire, drought and climate change) (Whinham & Chilcot 2002). Due to the rarity and vulnerability of Australian *Sphagnum* moss, and limited knowledge of the associated Australian desmid 'flora', it is critical to document the desmids in this threatened ecological community, not only as an inventory of biodiversity, but to also provide a tool for ecological monitoring, conservation and management of this rare and threatened ecosystem, and to facilitate broader wetland and climate change research.

The earliest Australian account concerning desmids collected from *Sphagnum* is from Playfair (1908) where species were recorded from a tract of *Sphagnum* near the coast in Coogee, Sydney (see Table 1). The species encountered were often in great abundance, forming pure gelatinous masses on the surface of the water. Of note was *Cosmarium glyptodermum* West & G.West, previously known solely from east and central Africa, but a dominant species now associated with Australian *Sphagnum* moss. This pioneering observation highlighted the difference in desmid composition from the well-studied, European counterparts. Few records have been made since, with Skinner (1979) providing additional data from a more elaborate study of the Zygnemaphyceae & Oedogoniophyceae from a range of environments from northern New South Wales. However, this study did not provide adequate sampling records to determine which species were directly collected from *Sphagnum*. The most recent study is an unpublished honours thesis by Darling (1982), who surveyed the algal epiphyton (including desmids) from *Sphagnum* hummocks growing around several ponds from Lake Mountain, Victoria. Based on these previous studies, the desmid flora from Australian *Sphagnum* appears to be rich in diversity, with species from the genera *Closterium* Nitzsch ex Ralfs and *Cosmarium* being a prominent component.

The aim of this study was to build upon previous work in Australia by surveying and recording the desmid 'flora' associated with *Sphagnum* within the New England Tablelands Bioregion and presenting the taxonomic results in the form of an illustrated synopsis. This work also explores aspects of their diversity with two of the *Sphagnum* habitats from the study area compared using a multimetric schema to assess their conservation value. Additionally, these assemblages were interpreted further by quantifying spatial patterns of beta diversity along with previous Australian studies that collected desmids from this kind of substrate. We lastly provide some context of how distinctive the Australian desmid flora is by contrasting it with their better-studied counterparts from central and western Europe.

Table 1. List of desmid taxa previously reported from *Sphagnum* in Australia with accepted taxa used for this study. Notes include the synonym/s used by the authors, objective (≡) or subjective (=). * Denotes a doubtful identification/misapplied name but with insufficient data to provide a certain, alternate identification.

Accepted name	Location	Reference	Notes
Saccoderm desmids:			
Cylindrocystis crassa	Lake Mountain	Darling (1982)	
Mesotaenium macrococcum	Lake Mountain	Darling (1982)	
Netrium digitus	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	≡ *Penium digitus*
Netrium oblongum	Lake Mountain	Darling (1982)	
Tortitaenia obscura	Coogee	Playfair (1908)	≡ *Spirotaenia obscura*
Placoderm desmids:			
Actinotaenium australe	Coogee	Playfair (1908)	≡ *Penium australe*
Actinotaenium cucurbita	Coogee	Playfair (1908)	≡ *Penium cucurbita*
Actinotaenium cf. *perminutum*	Lake Mountain	Darling (1982)	= *Cylindrocystis* cf. *minutissima*
Actinotaenium turgidum	Coogee	Playfair (1908)	≡ *Cosmarium turgidum*
Closterium acutum cf. var. *linea*			
Closterium closterioides	Coogee	Playfair (1908)	≡ *Penium libellula*
Closterium closterioides var. intermedium	Lake Mountain	Darling (1982)	Reassigned from misapplied name *Netrium* cf. *interruptum*
Closterium cynthia	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	
Closterium deplontei vars.	Coogee	Playfair (1908)	
Closterium dianae	Coogee	Playfair (1908)	
Closterium lunula	Coogee	Playfair (1908)	
Closterium navicula	Coogee	Playfair (1908)	≡ *Penium navicula*
Closterium nematodes & vars.	Coogee	Playfair (1908)	
Closterium rostratum	Lake Mountain	Darling (1982)	
Closterium striolatum	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	
Cosmarium amoenum vars.	Coogee	Playfair (1908)	
Cosmarium amplum	Coogee	Playfair (1908)	
Cosmarium boeckii vars.	Coogee	Playfair (1908)	
Cosmarium gayanum	Lake Mountain	Darling (1982)	
Cosmarium inconspicuum	Lake Mountain	Darling (1982)	
Cosmarium mesolium	Coogee	Playfair (1908)	
Cosmarium obsoletum	Lake Mountain	Darling (1982)	Reassigned from misapplied name *Cosmarium circulare*
Cosmarium orthopunctulatum	Coogee	Playfair (1908)	
Cosmarium pseudopyramidatum vars.	Coogee	Playfair (1908)	
**Cosmarium quadrifarium* var. *hexasticha*	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	≡ *Cosmarium quadrifarium* f. *hexasticha*; facial ornamentation not depicted nor described by Darling (1982)
**Cosmarium* cf. *quadrum*	Lake Mountain	Darling (1982)	Some other species of *Cosmarium* with an open sinus such as *Cosmarium reniforme* var. *compressum*
Cosmarium rectangulare	Lake Mountain	Darling (1982)	
Cosmarium reniforme var. *compressum*	Coogee	Playfair (1908)	
Cosmarium striolatum var. *nordstedtii*	Coogee	Playfair (1908)	= *Cosmarium glyptodermum sensu auctorum*
Cosmarium sp.	Lake Mountain	Darling (1982)	Similar to *Cosmarium spirale* observed in this study
Cosmarium subspeciosum	Coogee	Playfair (1908)	
Cosmarium tetragonum	Lake Mountain	Darling (1982)	
Cosmarium tinctum	Coogee	Playfair (1908)	
Cosmarium validius	Coogee	Playfair (1908)	*Nomen invalidum pro Cosmarium subspeciosum* var. *validius*

Accepted name	Location	Reference	Notes
Euastrum ansatum	Lake Mountain	Darling (1982)	
Euastrum dideltoides	Coogee	Playfair (1908)	
Euastrum insulare	Lake Mountain	Darling (1982)	
Euastrum neosinuosum vars.	Coogee	Playfair (1908)	≡ *Euastrum sinuosum* vars.
Euastrum validum	Lake Mountain	Darling (1982)	
Hyalotheca hians	Coogee	Playfair (1908)	
Micrasterias jenneri	Lake Mountain	Darling (1982)	
Micrasterias papillifera vars.	Coogee	Playfair (1908)	
Micrasterias tropica var. *indivisa*	Coogee	Playfair (1908)	≡ *Micrasterias euastroides* var. *indivisa*
Micrasterias truncata vars.	Coogee	Playfair (1908)	
Penium spirostriolatum	Coogee	Playfair (1908)	
Pleurotaenium crenulatum	Coogee	Playfair (1908)	
Pleurotaenium nodosum	Coogee	Playfair (1908)	
Pleurotaenium ovatum	Coogee	Playfair (1908)	
Staurastrum alternans	Coogee	Playfair (1908)	
**Staurastrum* cf. *chaetoceros*	Lake Mountain	Darling (1982)	Some other species of *Staurastra*; similar to *Staurastrum* cf. *hardyi* in this study.
Staurastrum inconspicuum	Lake Mountain	Darling (1982)	
Staurastrum submonticulsoum	Coogee	Playfair (1908)	
Staurodesmus connatus	Lake Mountain	Darling (1982)	
Staurodesmus triangularis	Lake Mountain	Darling (1982)	
Tetmemorus brebissonii	Coogee, Lake Mountain	Playfair (1908), Darling (1982)	
Tetmemorus laevis	Lake Mountain	Darling (1982)	
Xanthidium coogeanum	Coogee	Playfair (1908)	

Materials and Methods

Study sites

Sphagnum bogs are excellent sites to sample for desmids (Entwisle et al. 1997). However, many historical sites of desmid study, e.g. "Coogee" of Playfair (1908), are vague and have been degraded or destroyed by clearing and urbanisation. Vegetation surveys by Hunter and Sheringham (2008) indicated that only a few hectares of *Sphagnum* bogs are in good condition across the New England Tablelands. In the present study, selection of sample sites was based on a review of recent literature and our knowledge of the region (Figure 1). We focused on *Sphagnum* hummocks (terrestrial or partially submerged in ditches) and tracts of *Sphagnum* (in creeks, bogs and over granite surfaces). Thus, we sampled from Ebor Common (30°24'17.8"S 152°20'58.6"E) (n = 4), Basket Swamp (28°55'13.8"S 152°08'26.0"E) (n = 8), New England National Park (30°29'47.1"S 152°23'55.4"E) (n = 7), and Oaky Creek adjacent to Cathedral Rock National Park (30°29'35.6"S 152°15'19.6"E) (n = 4).

Sampling

Samples were collected by squeezing a handful of *Sphagnum* with the thumb pointed downwards to the opening of the vial or, the *Sphagnum* moss was pressed several times with a sample lid until water pooled and then the liquid was transferred to the sample vial. Sample acidity was tested by use of a calibrated pH probe (Multi-Parameter PCSTestr™ Eutech Instruments). Separate sub-samples were preserved within 48 hrs with Lugols iodine or 4% formalin. Unpreserved samples of small fragments of *Sphagnum* with the associated water matrix were also taken and intermittently kept in a fridge and near a window away from direct sunlight over several months.

Analysis of material

For light microscopy, semi-permanent slides were prepared by adding one to two drops of sample to a glass slide and covered using a 22 × 22 mm No. 1 coverslip with the edges sealed using clear nail polish. Drawings were produced using a Nikon drawing tube attached to a Nikon Optiphot2 microscope under brightfield microscopy. Photomicrographs were taken of the sampled material using a Nikon DS-5M camera coupled with a DS-L1 monitor. Measurements of cellular dimensions (see Table 2 for definitions of symbols and abbreviations) were taken from the digital images using MICAM version 2.0 developed by Marien van

Westen (2016). Digital illustrations presented herein were produced by largely following Montesanto (2015) with GIMP 2.8 software from either the prepared drawings or by series of photomicrographs of specimens at different focal planes, which were traced into a single image.

Table 2. Symbols and abbreviations defined.

Ap. = Breadth of apices
Br. = Breadth
Br. cpr. = Breadth with processes
Br. spr. = Breadth without processes
Br. csp. = Breadth with spines
Br. ssp. = Breadth without spines
I. = Isthmus
L. = Length
L:B = Ratio of length to breadth
L. cpr. = Length with processes
L. spr. = Length without processes
L. csp. = Length with spines
L. ssp. = Length without spines
Pr. = Length of processes
Sp. = Length of spines
Th. = Thickness of cell

Specimens prepared for scanning electron microscopy (SEM) were from material preserved in either formalin or Lugols iodine and directly mounted onto ethanol washed aluminium stubs and allowed to settle for at least 1 h. The top of the drop of sample was then wicked away to reduce water and hence drying time. The stubs were then placed in a glass bell jar with silicon beads and allowed to completely dry overnight. Stubs with the dried material were then sputter coated with gold. Cells were observed using a JSM-6610 Series Scanning Electron Microscope with voltage set at 15 kV, spot size 30, and the aperture at its most closed setting.

Descriptions based on light microscopy and/or scanning electron microscopy are indicated LM: and SEM:, respectively and are used to specify which technique was used to report our observations. This distinction is important since these techniques differ in their utility. For instance, SEM is able to facilitate the observations of submicroscopic features of the cell wall but is unable to resolve intracellular features such as chloroplast configuration.

Taxonomic determinations

Whole-group treatments were consulted for identification (Brook & Williamson 2010; Coesel & Meesters 2007; Croasdale & Flint 1988, 1989; Croasdale et al. 1994; Ling & Tyler 2000). Initial identification of examined specimens was compared with illustrations and the descriptions from the available literature. Most identifications were then cross-checked by using the available dichotomous keys, and/or comparison with the original protologue of the species or taxon.

Desmid taxonomy has a notoriously troubled history of numerous infraspecific taxa and synonymy resulting from disagreement on which entities constitute species (Kouwets 2008). For this study, as many specimens as possible were observed within the representative population to understand their morphological range and variability to delimit distinct species; i.e., morphologically defined species. Some entities here have been tentatively assigned to existing species with *cf.* before the specific epithet and infer it is most likely the species designated but additional enquiry is required for confirmation. Australian distribution records by state were based on relevant sources (Day et al. 1995; Entwisle & Nairn 2021; Ling & Tyler 2000).

Comparison & assessment of sampled habitats

Nature Conservation Value (NCV) for Basket Swamp and Ebor Common was determined with the aid of the computer program DesmidValue version 1.0 (23-11-2007) in Coesel & Meesters (2007), whereby the three parameters diversity (d), rarity (r) and ecosystem maturity/sensitivity (m) are scaled in their respective transformation schemes (D, R and M) based on the acidity of the sampled habitat (see tables 3, 4, 5). These scaled data have a maximum value of three for D & R and four for M, with a possible NCV score of 10. For the diversity parameter, not all species and their infraspecific taxa encountered in our survey were available to select and enter from the list of West-European species within the program and were excluded from the

analysis along with any unidentified taxa. Rarity and Maturity values associated with the desmid taxa in DesmidValue were left as default.

Table 3. Transformation scheme for Diversity scores (D) following Coesel & Meesters (2007).

Diversity			
neutral-alkaline	slightly acidic	highly acidic	
Species richness (d)	Species richness (d)	Species richness (d)	Conservation value (D)
1–5			1
6–30			2
>30			3
	1–10		1
	10–50		2
	>50		3
		1–5	1
		6–30	2
		>30	3

Table 4. Transformation scheme for Rarity scores (R) following Coesel & Meesters (2007).

Diversity			
neutral-alkaline	slightly acidic	highly acidic	
Rarity (r)	Rarity (r)	Rarity (r)	Conservation value (R)
1–2			1
3–10			2
>10			3
	1–5		1
	6–40		2
	>40		3
		1–2	1
		3–30	2
		>30	3

Table 5. Transformation scheme for Ecological maturity scores (M) following Coesel & Meesters (2007)

Ecol. maturity			
neutral-alkaline	slightly acidic	highly acidic	
Ecol. maturity (m)	Ecol. maturity (m)	Ecol. maturity (m)	Conservation value (M)
1–5			1
6–20			2
21–40			3
>40			4
	1–10		1
	11–40		2
	41–80		3
	>80		4
		1–5	1
		6–20	2
		21–40	3
		>40	4

Additionally, a customised NCV scheme was also devised to compare and note any differences from the standard scheme based on desmids from European habitats and conditions. Here, species richness (d) remained unaltered but rarity (r) values were replaced with frequency data from a comprehensive water quality study on planktic and benthic desmids collected from 150 sampling sites (reservoirs, ponds swamps and bogs) over various catchments located throughout Thailand, south-east Asia by Ngearnpat (2009). The frequency rating of the attached/benthic desmids from Table 2 in Ngearnpat (2009) were converted to the following values: very rare (+) to 3, rare (++) to 2, occasional (+++) to 1 and frequent (++++) to 0. Taxa not encountered by Ngearnpat (2009) were left blank *i.e.* not assigned any value (See table 7). As suggested by Coesel & Meesters (2007) for users from non-European continents, the ecosystem sensitivity (m) criterion above was replaced with one based on endemism (e). The endemism scheme here assigned values to species with non-cosmopolitan distributions that scaled-down if they were deemed less geographically isolated; *viz.*, values for species that are putative Australian endemics = 4, species from within a designated, single desmid bioregion (e.g. Indo-Malay and northern Australia; IMNAR; southern Australia and New Zealand; SANZ) = 3, species with apparent climatic distributions (e.g. pantropical, alpine) = 2, species with broader distributions that are not well defined but not as widespread (e.g. disjunct, southern hemisphere, or bioregions combined) = 1 and cosmopolitan species = 0 (see Table 7). The transformation schemes that generated the D, R and E values that contributed the modified NCV were the same as the original D, R, M above (*see* tables 3, 4 & 6).

Table 6. Transformation scheme for proposed Endemism scores (E) based on the Ecological maturity scheme from Coesel & Meesters (2007).

Endemism			
neutral-alkaline	slightly acidic	highly acidic	
Endemism (e)	Endemism (e)	Endemism (e)	Conservation value (E)
1–5			1
6–20			2
21–40			3
>40			4
	1–10		1
	11–40		2
	41–80		3
	>80		4
		1–5	1
		6–20	2
		21–40	3
		>40	4

The data from Basket Swamp and Ebor Common (Table 7) were combined with the species lists from Playfair (1908) and Darling (1982) (Table 1) to create a presence/absence data set of all four sites in Australia. Community composition and beta diversity partitions, including nestedness, of the combined *Sphagnum*-associated desmids listed from Australia (as presence/absence data) were assessed using R 4.1.1 (2021-08-10) -- "Kick Things" (R Core Team 2021). The "nestedtemp" function in the Vegan package (version 2.5-7) of Oksanen et al. (2020) was used to determine if the species-poor communities shared subsets with richer ones. The resultant matrix temperature is a measure between 0 and 100, where 0 is indicative of being perfectly nested whereas 100 is suggestive of a completely random species distribution pattern. Beta diversity of the above-mentioned data set was also evaluated using the "nestedbetasor" function in Vegan. Here, Sørensen dissimilarity (β_{SOR}), Simpson dissimilarity (β_{SIM}) and Nestedness-resultant dissimilarity (β_{NES}) indices as proposed by Baselga (2010) were returned. The β_{RATIO} index was obtained by dividing the resultant β_{NES} by β_{SIM} indices to determine whether beta diversity in the tested communities were dominated by species turnover (<0.5) or by nestedness (>0.5).

Results & Discussion

The results and discussion of the present study have been arranged into two sections, Ecology and Taxonomy. Section I: Ecology, deals principally with the aspects of alpha- and beta-diversity, conservation assessment and nestedness of the *Sphagnum*-associated desmids surveyed locally and abroad. Two of the study sites, Basket

Swamp and Ebor Common, were assessed for conservation value based on an existing and updated scheme. Basket Swamp received high scores due to greater diversity and the presence of numerous rare and endemic species. Ebor Common scored lower due to less species richness and fewer endemics. By combining our data set with previous surveys in Australia, we found that *Sphagnum*-associated desmid communities were highly diverse (β_{SOR} = 0.82). Despite the presence of common species at different sites, our findings suggest spatial turnover is the dominate factor in these assemblages, instead of nestedness (β_{RATIO} = 0.15). Section II: Taxonomy, is a summary and synoptic treatment of the taxonomic diversity we encountered. Of the 80 taxa recovered, 16 are new distribution records for New South Wales or Australia. Additionally, two taxonomic novelties are also described - *Micrasterias bicoronata* A.Kenins and *Cosmarium phymatodeum* A.Kenins. Aspects of biogeography and potential issues of conspecificity and crypsis have also been highlighted in this section.

Section I: Ecology

Desmids as bioindicators in Australia

Two sites, Basket Swamp (pH 4.4–5.8) and Ebor Common (pH 4.0–4.9), had the most diversity of sites surveyed in this study, and their desmid species-composition was compared (Tables 7, 8 and 9). A total of 69 desmids was recorded from Basket Swamp, with many well-known, cosmopolitan species associated with habitats rated as acidophilic and oligotrophic to oligo-mesotrophic. A small proportion of species with broader ecological tolerances was also present (Table 7). Ebor Common had fewer species of desmids (18), and were exclusively associated with acid conditions and tended to be oligo-mesotrophic (Table 7). Basket Swamp also had far greater numbers of endemic and geographically isolated taxa than Ebor Common (Table 7). Five species (*Actinotaenium cucurbitinum* (Bisset) Teiling, *Docidium baculum* Brébisson ex Ralfs, *Micrasterias jenneri* Ralfs, *Penium exiguum* West and *Staurastrum inconspicuum* Nordstedt) designated from Dutch habitats as "Red List" species were also detected from Basket Swamp, whereas none was recovered from Ebor Common.

Table 7. List of taxa found at Basket Swamp and Ebor Common with their ecological status, Rarity values based on Ngearnpat (2009) and proposed Endemism values.

Species/Taxa	Basket Swamp	Ebor Common	Ecology	Rarity value	Endemism value
Actinotaenium cucurbitinum	+		Acidophilous, oligotrophic	2	0
Actinotaenium diplosporum var. *americanum*		+	Acidophilous, meso- to oligotrophic		0
Actinotaenium cf. *phymatosporum*	+		Acidophilous, oligo-mesotrophic		
Closterium abruptum var. *brevius*	+	+	Oligotrophic, acidobiontic		0
Closterium cf. *calosporum*	+	+	Acidophilous, mesotrophic	3	0
Closterium closterioides	+		Acidobiontic, oligotrophic		0
Closterium closterioides var. *intermedium*	+	+	Acidobiontic, oligotrophic	2	0
Closterium cynthia	+		Acidophilous, oligo-mesotrophic	3	0
Closterium dianae var. *arcuatum*	+		Mesotrophic	3	0
Closterium kuetzingii var. *procerum*	+				3
Closterium lunula	+		Acidophilous	3	0
Closterium navicula	+	+	Acidophilous, oligo-mesotrophic	2	0
Closterium striolatum	+		Acidobiontic, oligo-mesotrophic	2	0
Cosmarium amplum	+				2
Cosmarium amoenum	+	+	Acidophilous, oligotrophic		0
Cosmarium annulatum	+		Acidophilous		0
Cosmarium askenasyi	+			2	2
Cosmarium contractum	+		Acidophilous-circumneutral, oligo-mesotrophic	1	0
Cosmarium cf. *difficile* var. *messikommeri*		+	Acidophilous		
Cosmarium cf. *difficillimum*	+				
Cosmarium dorsitruncatum	+			3	2
Cosmarium margaritiferum f. *regularius*	+		Acidophilous		0
Cosmarium obsoletum var. *sitvense*	+			0	1
Cosmarium phymatodeum	+				4
Cosmarium quadrifarium var. *simplex*	+	+			2

Species/Taxa	Basket Swamp	Ebor Common	Ecology	Rarity value	Endemism value
Cosmarium regnellii	+		Acidophilous-alkaliphilous, meso-eutrophic	1	0
Cosmarium cf. *reniforme var. compressum*	+		Acidophilous- alkaliphilous, meso-eutrophic		
Cosmarium spirale	+				3
Cosmarium subadoxum	+		Acidophilous, mesotrophic	3	0
Cosmarium striolatum var. *nordstedtii*	+				2
Cosmarium cf. *difficillimum*	+				
Cosmarium cf. *zonatum* var. *compressum*	+				
Cylindrocystis brebissonii var. *minor*	+		Acidophilous	3	0
Cylindrocystis crassa	+		Acidophilous, oligotrophic, (sub) atmophytic	3	0
Cylindrocystis cf. *brebissonii* var. *turgida*	+				
Cylindrocystis cushleckae	+		Acidophilous, oligotrophic, (sub) atmophytic		
Cylindrocystis gracilis	+		Acidophilous, meso-oligotrophic		
Docidium baculum	+		Acidophilous, oligotrophic		0
Euastrum ansatum	+	+	Acidophilous, meso-oligotrophic	1	0
Euastrum ansatum var. *simplex*	+	+			0
Euastrum cf. *ansatum* var. *triporum*	+				0
Euastrum denticulatum var. *quadrifarium*	+				0
Euastrum didelta var. *bengalicum*	+				2
Euastrum longicolle var. *australicum*	+				3
Euastrum cf. *longicolle* var. *australicum*	+				0
Euastrum neosinuosum var. *germanicum*	+			2	0
Groenbladia bourrellyi	+				0
Mesotaenium endlicherianum	+		Acidophilous		0
Micrasterias bicoronata	+				4
Micrasterias decemdentata	+		Acidophilous, mesotrophic		0
Micrasterias jenneri	+		Acidophilous, oligotrophic		0
Micrasterias nordstedtii f. *australiensis*	+				4
Micrasterias thomasiana var. *notata*	+		Acidophilous, oligo-mesotrophic		0
Micrasterias truncata var. *crenata*		+	Acidophilous, meso-oligotrophic		0
Netrium digitus complex	+	+	Acidophilous	1	0
Penium exiguum	+		Acidophilous, oligotrophic		0
Pleurotaenium ehrenbergii	+		Acidophilous, mesotrophic	1	0
Pleurotaenium nodosum	+			3	0
Pleurotaenium tridentulum	+		Acidophilous		0
Spirotaenia condensata		+	Acidophilous, oligo-mesotrophic	3	0
Spirotaenia sp.		+			
Staurastrum aureolatum	+			3	2
Staurastrum cf. *hardyi*	+				
Staurastrum inconspicuum	+		Acidophilous, oligotrophic		0
Staurastrum cf. *longebrachiatum*	+				
Staurastrum cf. *monticulosum*	+				
Staurastrum trihedrale		+			2
Staurodesmus cf. *cuspidicurvatus*	+				
Tetmemorus brebissonii	+		Acidophilous, oligotrophic		0
Tetmemorus granulatus	+	+	Acidophilous, meso-oligotrophic	2	0
Tetmemorus cf. *laevis*	+	+	Acidophilous, oligotrophic		
Triploceras gracile	+		Oligotrophic	1	2
Tortitaenia obscura		+	Acidophilous, oligo-mesotrophic		0
Xanthidium armatum var. *basidentatum*	+				3
Xanthidium octocorne	+		Acidophilous, oligotrophic		0
Xanthidium cf. *octonarium*	+				

The presence of some desmids deemed as acidobiontic-neutral at Basket Swamp indicated potential acidity fluctuation across the sampled habitat, so the values for both kinds of acidic conditions (slightly and highly) are reported here. The Basket Swamp survey had a NCV score of 8 from DesmidValue and 10 from the modified scheme when calculated with water type set as highly acidic and scores of 7 and 9, respectively, with a slightly acidic water type (see Tables 8 and 9). Differences between the scores from the two marking schemes were influenced by the adjusted rarity values and change from ecological maturity to endemism values. The diversity value (species richness) was unaffected (Figure 2). The modified NCV score for Basket Swamp may be conservative when considering the potentially novel/unnamed forms (e.g. *Cylindrocystis* cf. *brebissonii var. turgida* Schmidle, *Euastrum* cf. *longicolle* var. *australicum* Playfair) and tentatively identified species (e.g. *Cosmarium* cf. *neapolitanum* var. *australicum* Schmidle, *Staurastrum* cf. *hardyi* G.S.West and *S.* cf. *monticulosum* Brébisson) may increase the final mark in the endemism section.

Table 8. Calculated NCV based on the DesmidValue Version 1.0 program by Coesel & Meesters (2007) developed for European lowland areas. (HA) = highly acidic, (SA) slightly acidic conditions selected.

Site	Diversity	Rarity (R)	Maturity (M)	NCV (D+R+M)
Basket Swamp	69 species = **3** (see table 7)	**4 Very rare:** *A. cucurbitinum*, *D. baculum*, *M. jenneri*, *S. inconspicuum*; **3 Rare:** *C. closterioides* var. *closterioides*, *C. crassa*, *P. exiguum*; **9 Rather Rare:** *C. cynthia*, *C. lunula*, *C. navicula*, *C. amoenum*, *C. contractum*, *P. ehrenbergii*, *T. brebissonii*, *T. laevis*, *X. octocorne* = **27** which transforms to **2**.	**3 Most Indicative:** *D. baculum, M. jenneri, S. inconspicuum;* **11 Indicative:** *A. cucurbitinum, C. closterioides* var. *closterioides, C. cynthia, C. lunula, C. navicula, C. amoenum, C. contractum, P. exiguum, T. brebissonii, T. laevis, X. octocorne*; **2 Somewhat Indicative:** *E. ansatum*, *P. ehrenbergii* = **33** which transforms to **2 (SA)** or **3 (HA).**	(3)+(2)+(2 or 3) = **7 (SA) or 8 (HA)/10**, depending on acidity level selected.
Ebor Common	18 species = **2** (see table 7)	**2 Rare:** *S. condensata*, *T. obscura*; **3 Rather Rare:** *C. navicula*, *C. amoenum*, *T. laevis*, *N. digitus* = **8** which transforms to **2**	**3 Indicative:** *C. navicula*, *C. amoenum, T. laevis*; **1 Somewhat Indicative:** *E. ansatum*, = **7** which transforms to **2**	(2)+(2)+(2) = **6/10**

Table 9. Calculated NCV based on modified scheme more suited to the Australian desmid flora using modified rarity values and an endemism criterion instead of ecosystem maturity. (HA) = highly acidic, (SA) slightly acidic conditions selected.

Site	Diversity	Rarity (R)	Endemism (E)	NCV (D+R+E)
Basket Swamp	69 species = **3** (see table 7)	**10 Very rare:** *C.* cf. *calosporum*, *C. cynthia*, *C. dianae* var. *arcuatum C. lunula*, *C. dorsitruncatum, C. subadoxum*, *C. brebissonii* var. *minor*, *C. crassa*, *S. aureolatum*; **5 Rare:** *A. cucurbitinum*, *C. closterioides* var. *intermedium*, *C. navicula*, *C. striolatum, C. askenasyi*; **9 Occasional:** *C. contractum*, *C. regnellii*, *E. ansatum*, *E. denticulatum*, *E. neosinuosum* var. *germanicum*, *N. digitus*, *P. ehrenbergii*, *P. nodosum*, *T. granulatus, T. gracile* = **49** which transforms to **3**.	**3 Australian endemics:** *C. phymatodeum*, *M. bicoronata*, *Micrasterias nordstedtii* f. *australiensis*; **2 IMNAR:** *C. amplum*, *C. spirale*; **3 SANZ:** *C. kuetzingii* var. *procerum*, *E.* *longicolle* var. australicum, *X. armatum* var. *basidentatum*; **7 Climatic:** *C. askenasyi*, *C. dorsitruncatum, C.* *striolatum* var. *nordstedtii*, *C. quadrifarium* var. *simplex, E. didelta var. bengalicum, S. aureolatum* and *T. gracile* & **1 Broader:** *C. obsoletum* var. *sitvense* = **42** which transforms to **3 (SA)** or **4 (HA).**	(3)+(3)+(3 or 4) = **9 (SA) or 10 (HA)/10**, depending on acidity level selected.
Ebor Common	18 species = **2** (see table 7)	**2 Very rare:** *C.* cf. *calosporum*, *S. condensata*; **2 Rare:** *C. closterioides* var. *intermedium*, *C. navicula*; **2 Occasional:** *E. ansatum*, *N. digitus* = **12** which transforms to **2**	**2 Climatic:** C. *quadrifarium* var. *simplex*, *Staurastrum trihedrale* = **4** which transforms to **1**	(2)+(2)+(1) = **5/10**

Ebor Common had a lower NCV mark of 6 and 5 for both schemes (Tables 8 and 9). While there was substantial species diversity at this site, the species were relatively common, with only a few regional endemics (*Cosmarium quadrifarium* var. *simplex* Krieger, *Staurastrum trihedrale* Wolle). Rarity (R) values that formed part of the NCV from both schemes were the same despite the use of different scoring criteria for Ebor Common. However, the modified NCV scheme that used Endemism (E) values scored lower than the original

Ecological maturity (M) values for this site (compare Tables 8 & 9). This difference was due to the presence of more m-linked desmids than e-linked in the data set. It should be also noted that if *Cosmarium* cf. *difficile* var. *messikommeri* (Croasdale) Kouwets (which is encountered in artic alpine habitats) was confirmed from this site, it would raise the final mark to 6 for the modified NCV using the endemism schema. Furthermore, the presence of *Staurastrum trihedrale* is a new record for Australia and is thus far only found at this site.

Application of an NCV based on Coesel (2001) in conjunction with a modified one to better suit the Australian desmid flora resulted in some slight differences from the same data set. Basket Swamp was awarded a relatively high NCV score of 7.5 and 9.5 (averaged over slightly and highly acidic conditions) from the original and modified scheme. However, a breakdown of each criterion found a consistently lowered score for either R or M/E in the original, European-based scheme in DesmidValue (see fig. 2). These different values are likely due to many of the species encountered from Basket Swamp not present in the original species scoring list. Consequently, these species could not contribute to the overall NCV score which may suggest the original scheme has the potential to underestimate conservation value outside of western Europe if used in its original state. In contrast, Ebor Common was awarded a relatively lower score (6 from DesmidValue and 5 from modified) due to fewer species of desmids being encountered; combined with very few of these having limited geographic distributions. However, since our sampling approach focussed exclusively on *Sphagnum,* combined with particular unidentified species that may be novel and/or geographically isolated, the NCV's of both sites should be considered preliminary until a more thorough survey is undertaken. Overall similar scores from using different values is not unexpected. Fehér (2007) and Krasznai et al. (2008) used modified rarity values from Hungarian waters and found little difference in overall NCV scores when comparing the different rarity values. This insignificance in using different values may indicate a bias in this scoring system whereby high diversity (d) has a major influence upon the overall NCV score due to an increased likelihood of r- and m-linked desmids being present to contribute to R and M. Quantifying species abundance, and the use of relative rarity (average r/d) and relative maturity (average m/d) has been adopted to reduce this bias (Fehér 2007; Krasznai et al. 2008).

The devised scheme here based on Coesel (2001) in Coesel & Meesters (2007) is not restricted for the sole purpose of determining conservation value of wetlands but can also be used as a proxy to assist environmental monitoring for purposes such as remediation to observe trends over time; see Coesel (2003). The scheme has an additional advantage that it can also be calculated based on data from previous surveys of wetlands that have detailed accounts of desmids and used as part of a much larger set of data that includes a historical account (see Hansen et al. 2018 for a recent example). Limitations of the scheme include the presence of species complexes, which may result in underestimated diversity and endemism and therefore score. This, however, could hypothetically be overcome by the use of morphological disparity as an alternative, or in conjunction with, traditional measures of biodiversity (species richness) which preliminary analysis from Neustupa et al. (2009) has shown has potential in desmids. Another limitation of the modified scheme developed for Australia is that it is currently non-quantitative, however Krasznai et al. (2008) included quantification methods (enumeration) in their study of Hungarian oxbow lakes, so a similar approach could be adopted for future studies. The overall suitability of rarity values based on desmids from Thailand by Ngearnpat (2009) is unclear, but due to our incomplete knowledge of their occurrence in Australia, it was deemed the most appropriate data set to employ since it shares a similar desmid flora that is within the same biogeographic region (IMNAR). Lastly, this scheme is only truly applicable to freshwater lentic wetlands, and not fast-flowing lotic systems, or sites that frequently dry up (such as the atmophytic *Sphagnum* cushions sampled from this survey) as they have minimal desmid diversity. This last limitation is a particular issue since many Australian wetlands dry up and refill seasonally due to the water regime (Boulton et al. 2014). A remedy to this would involve sampling during "boom" rather than "bust" cycles during assessment, which was a sampling strategy employed by Casanova & Powling (2014) on temporary wetlands in western Victoria that included desmids. Ultimately, the modified scheme seems feasible but more sites from various locations from Australia need to be studied to further improve our understanding of the Australian desmid flora and its distribution, to fine-tune the proposed marking system.

Diversity of Australian Sphagnum*-associated Desmids*

The collated list of *Sphagnum*-associated desmids from Basket Swamp and Ebor Common (this study) along with the previous studies by Playfair (1908) and Darling (1982) totalled 115 different taxa, with a mean of 39 per site (see Figure 3). Some of the *Sphagnum*-associated taxa in the combined data set were grouped at the rank of species due to inconsistencies in the identification at the infraspecific level in those other studies. These were: *Netrium digitus* (Brébisson ex Ralfs) Itzigsohn & Rothe, *Cosmarium amoenum* Brébisson ex Ralfs, *Cosmarium obsoletum* (Hantzch) Reinsch, *Cosmarium quadrifarium* P.Lundell, *Euastrum ansatum* Ehrenburg ex Ralfs, *Euastrum neosinuosum* Anissimova & Guiry and *Micrasterias truncata*. Additionally, we have included '*Cosmarium validius*' (as listed in Playfair 1908), under *Cosmarium subspeciosum* var. *validius* Nordstedt

since it is a *nomen nudum* that is likely to have referred to the latter name. Certain species from the previous studies were also re-identified in this study based on the figures and descriptions provided, with *Netrium cf. interruptum* (Brébisson ex Ralfs) Lütkemüller reassigned to *Closterium closterioides* var. *intermedium* (Roy & Bisset) Růžička and *Cosmarium circulare* Reinsch reassigned to *Cosmarium obsoletum* in Darling (1982). *Cosmarium glyptodermum* cited in Playfair (1908) was reassigned to *Cosmarium striolatum* var. *nordstedtii* (Möbius) Krieger as it was considered to be synonymous for the latter species in Australia.

Species richness varied, with Basket Swamp having the highest number of taxa (67) and Ebor Common the lowest (17). The coastal bog site in Coogee studied by Playfair and the Lake Mountain ponds by Darling were intermediate with 40 and 31 taxa present, respectively. The species assemblages from each site were found to be largely dissimilar ($\beta_{SOR} = 0.82$) with beta-diversity patterns being attributed mainly to species turnover ($\beta_{SIM} = 0.71$) instead of nestedness ($\beta_{NES} = 0.10$). The resultant β_{RATIO} index of 0.15, confirmed that turnover was the dominant contributor to beta diversity in these communities. Nestedness temperature analysis (Fig. 3) also indicated that nestedness was weak, with a nested temperature of 37.1 and matrix fill of 34%. Only *Netrium digitus* and *Cosmarium quadrifarium* (infraspecific taxa included) were shared between all four sites. These two taxa have broad species concepts (see taxonomic account below) and thus diversity may be underestimated, overestimating the degree of nestedness reported here. Taxa found in at least three of the four evaluated sites were: *Closterium closterioides* var. *intermedium*, *Closterium cynthia* De Notaris, *Closterium navicula* (Brébisson) Lütkemüller, *Closterium striolatum* Ehrenberg ex Ralfs, *Cosmarium amoenum* varieties, *Euastrum ansatum* varieties, *Tetmemorus brebissonii* Ralfs and *Tetmemorus* cf. *laevis* Ralfs ex Ralfs. Considering the relatively cursory sampling efforts from these studies, overall nestedness may be underestimated due to inadequate sampling. A more comprehensive sampling effort that takes microhabitat heterogeneity into account as well as temporal and seasonal factors is needed to test and verify these initial findings.

Most of the common species encountered here are found in desmid floras abroad where they are considered benthic, acidophilous and often collected from *Sphagnum* moss. Furthermore, the majority (47.5%) of the desmids identified in this study were categorised as such (see Table 7) and is probably an underestimation considering the presence of poorly-known species with unclassified ecological status. Desmids with broader ecological preferences were also encountered, suggesting migration from nearby microhabitats. It has been hypothesised that high desmid diversity found in *Sphagnum* is due to the host plants' pH reducing capabilities of the surrounding water, making conditions more favourable for desmids (Brook 1981). Mutinová et al. (2016) have reported substrate preference for *Sphagnum* in certain microalgal groups (including desmids) from a European setting and suggest they likely provide a refuge for these acid-adapted organisms. These substrate qualities may be a significant factor for why we observed the presence of different as well as some shared species assemblages between all four sites despite Ebor Common having a poorer desmid biota. Subsequently, *Sphagnum*-harbouring sites in Australia are all potential targets for conservation since rare and/or endemic species can occur in both species-rich and -poor communities due to high spatial turnover. Using the above NCV scheme may assist in determining priority over certain areas or types wetlands with *Sphagnum*, if required.

The Australian desmid flora associated with *Sphagnum* share some similarities to but also marked differences from their better-studied counterparts of western and central Europe. Species of the genera *Cylindrocystis* and *Tetmemorus* were some of the most commonly encountered desmids in this investigation, and are also commonly found amongst *Sphagnum* in central and western European wetlands (Dell'Uomo & Pellegrini 1993; Coesel & Meesters 2007). Species such as *Micrasterias jenneri* and *Tetmemorus brebissonii* are typical of oligo-dystrophic desmid communities of boggy pools with *Sphagnum* from western Europe and were also encountered in the present study. However, many other 'European' species associated with this community are yet to be encountered in Australia (e.g. *Euastrum ampullaceum* Ralfs, *Euastrum crassum* Ralfs, *Micrasterias oscitans* Ralfs *s.s.*, *Staurastrum scabrum* Brébisson, *Staurastrum hystrix* Ralfs). Instead, putative endemics and tropical species such as *Cosmarium amplum* Nordstedt, *C. striolatum* var. *nordstedtii, Euastrum neosinuosum* varieties and *Pleurotaenium nodosum* (Bailey ex Ralfs) Lundell were recovered and were also reported from the previously cited desmid surveys of Australian *Sphagnum*. Further collections from Australian *Sphagnum* would allow a more meaningful assessment of their status and could be compared to those from Europe.

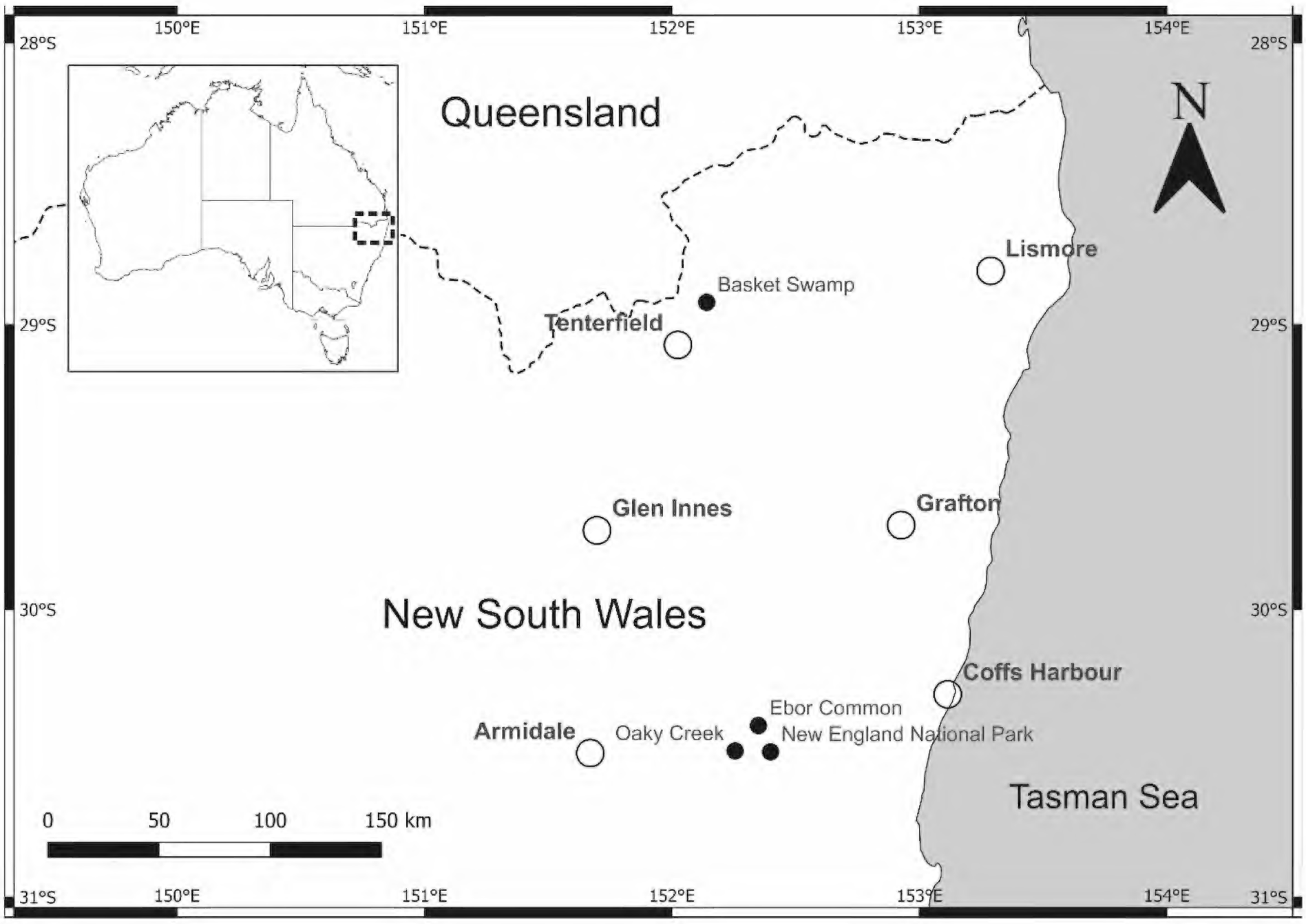

Fig. 1. Map displaying location of study sites designated with a black circle.

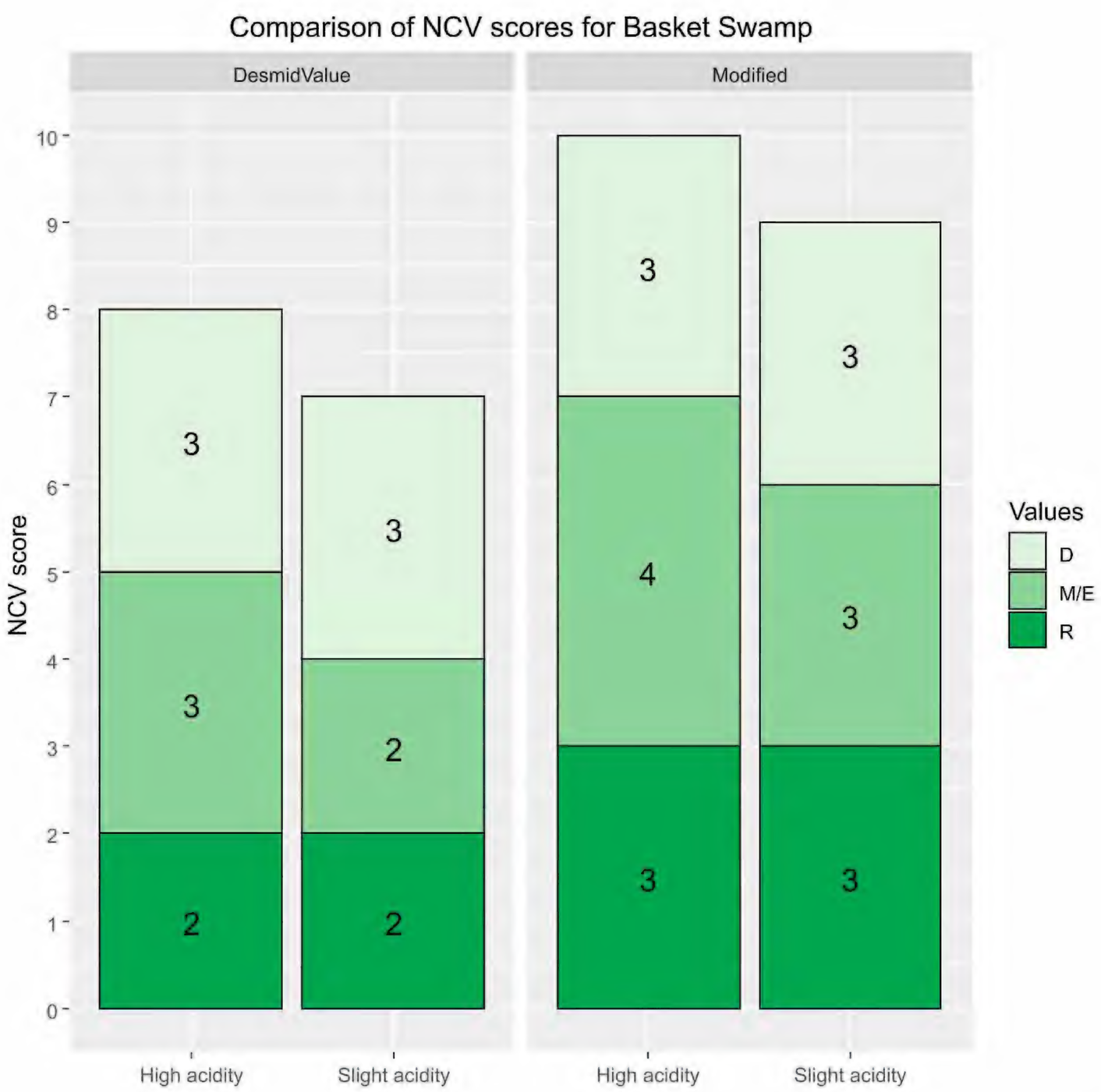

Fig. 2. Bar chart comparing the original DesmidValue scoring results versus the modified one for the Basket Swamp data at different conditions of acidity; D = Diversity value; R = Rarity value; M/E = Ecosystem maturity/Endemism value.

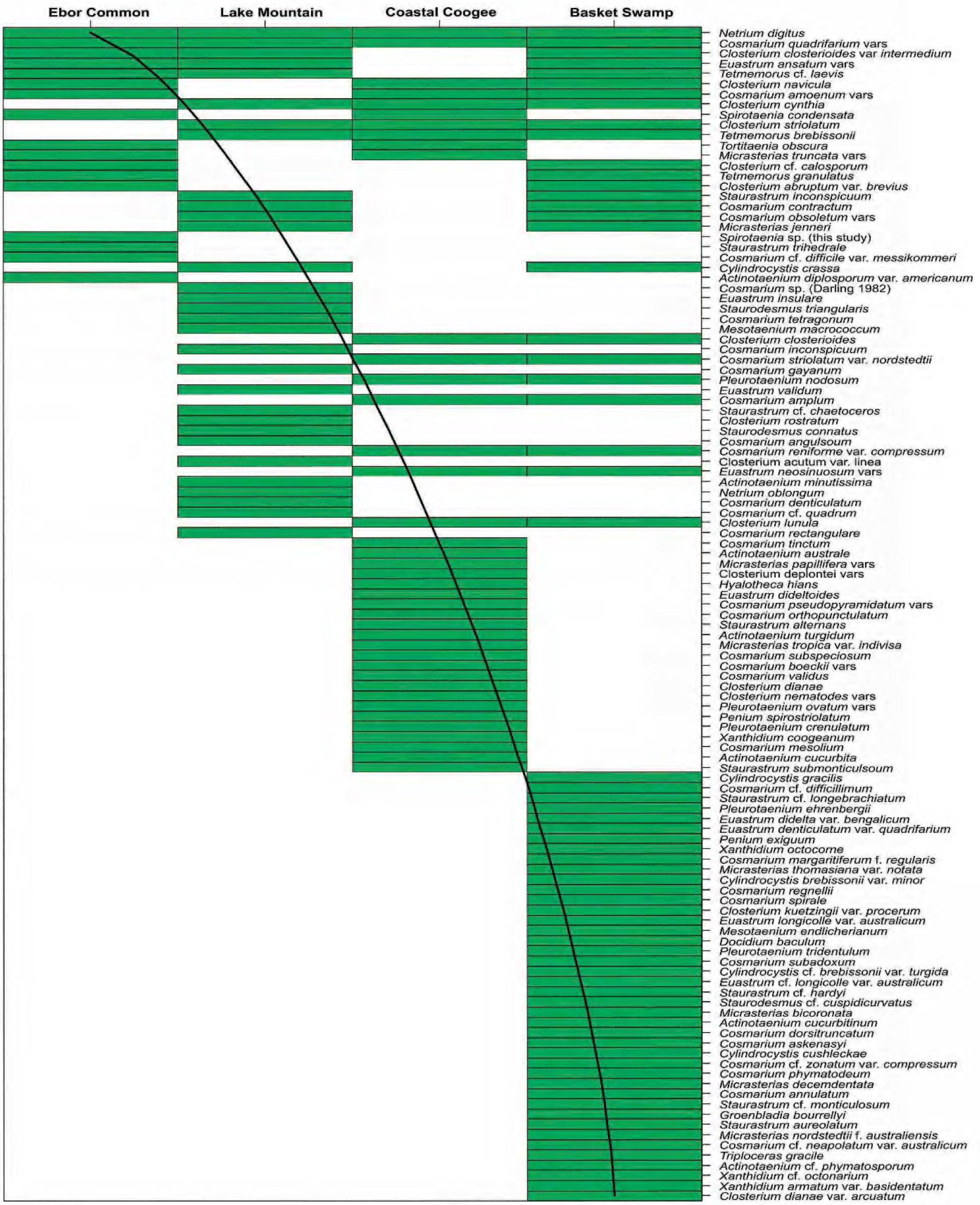

Fig. 3. Incidence matrix from tempnestedness analysis on the combined *Sphagnum*-associated desmids species list from Australia. Green bars represent taxa presence, white represents absence. Black, curved line represents isoclines of species nestedness where some species (e.g. *Netrium digitus*) are present at both lower (Ebor Common) and higher (Basket Swamp) diversity sites.

Section II: Taxonomy

Taxonomic diversity encountered

Eighty species and infraspecific taxa of desmids belonging to 19 genera were encountered. Of these, nine are newly recorded for Australia and seven are new to New South Wales; two are proposed as new species

(*Cosmarium phymatodeum* A.Kenins and *Micrasterias bicoronata* A.Kenins). Together with Skinner's (1979) publication, 125 desmids are now accounted for from this area. Some uncertain desmids that have also been described previously by Skinner (1977) from this same bioregion include *Cylindrocystis* sp. (as *C.* cf. *brebissonii var. turgida* here) and *Euastrum* sp. aff. *longicolle* (as *E.* cf. *longicolle* var. *australicum* here). A further 15 desmids have been tentatively assigned to known species in this study: *Closterium* cf. *calosporum* Wittrock, *Actinotaenium* cf. *phymatosporum* (Nordstedt) Kouwets & Coesel, *Cosmarium* cf. *difficile* var. *messikommeri*, *C.* cf. *neapolitanum* var. *australicum*, *C.* cf. *zonatum* var. *compressum* (Schmidle) Krieger & Gerloff, *Euastrum* cf. *luetkemuelleri* var. *laterepunctatum* A.M.Scott & Prescott, *Staurastrum* cf. *avicula* Brébisson, *S.* cf. *monticulosum* and *Tetememorus* cf. *granulatus* Brébisson ex Ralfs. Additional sampling is needed to observe more of these entities in greater abundance to study their polymorphism and life cycle (e.g. sexual reproduction of zygospores) for certain identification and/or a more extensive literature survey to confirm their identities. Lastly, doubt remains concerning *Cosmarium* cf. *difficillimum* Playfair, *C.* cf. *reniforme* var. *compressum* Nordstedt, *Staurastrum* cf. *hardyi* and *Xanthidium* cf. *octonarium* Nordstedt due to their inadequate descriptions through which apparent slight differences observed here may or may not be minor for the species in question. Re-examination and comparison of any original material from Möbius's, Nordstedt's, Playfair's, Schmidle's and West's work on the Australian desmids (and other species described from overseas in general) is required to reduce these uncertainties. Many of the doubtful forms documented here may assist future efforts in better species circumscriptions, as in the case of *Micrasterias nordstedtii* f *australicum* Thomasson and *M. bicoronata* rediscovered in this survey. As emphasised above, desmid taxonomy (in Australia and abroad) is hindered by the customary approach of defining species on certain morphological features, leading to numerous infraspecific taxa and confusion as to what entities truly represent species. The unified species concept (*see* De Queiroz 2007) which promotes utilising multiple sources of evidence (morphological, molecular, ecological and biogeographical data) to determine discontinuities in species boundaries has been successfully applied on desmids in Europe by Nemjova et al. (2011), Neustupa et al. (2011) and Šťastný et al. (2013). Use of this integrated approach would greatly assist in resolving the above-mentioned taxonomic uncertainties encountered here.

Observations from the SEM component of this study match those of the same previously studied species also encountered here, finding no evidence of cryptic diversity at the ultrastructural level. One exception could be the slight and possibly insignificant differences of *C. striolatum* var. *nordstedtii* from the African and Australian continents where there is disagreement on whether they are conspecific. This study has also examined the ultrastructure of a few species (including Australian "endemics") for the first time, e.g. *Cosmarium* cf. *difficillimum*, *Euastrum longicolle* var. *australicum* Playfair, *Cosmarium quadrifarium* var. *simplex*, *C. phymatodeum* sp. nov., *Micrasterias bicoronata* sp. nov. and *Staurastrum* cf. *hardyi*. Other species with broader distributions such as *Cosmarium annulatum* (Nägeli) De Bary, *C. subadoxum* Grönblad and *Staurastrum inconspicuum* that have been examined here can serve as a baseline to compare with overseas populations.

Our understanding of the geographical distribution of desmids in Australia is inadequate due to limited sampling, focused on certain parts of the continent (Coesel & Dingley 2005). Despite this, there is recognition that some species (and infraspecific taxa) are part of a north versus south flora which are encompassed within the much larger biogeographic regions of the Indo-Malay and northern Australia (IMNAR) and southern Australia and New Zealand (SANZ) (Coesel 1996; Vyverman 1996). Possible IMNAR representatives from here are *Euastrum* cf. *luetkemuelleri* var. *laterepunctatum, Cosmarium amplum* and *C. spirale* (Playfair) Krieger & Gerloff, in addition to three SANZ representatives here being *Closterium kuetzingii* var. *procerum* Skuja, *Euastrum longicolle* var. *australicum* and *Xanthidium armatum* var. *basidentatum* Nordstedt. The New England region appears to be within an interface of the two zones, as originally suggested by Skinner (1979). Distributions that seem to be climatically-defined, *i.e.* pantropical, are also observed in desmids (Coesel 1996), with examples of pantropical species from this survey being *Cosmarium askenasyi* Schmidle, *C. striolatum* var. *nordstedtii*, *C. quadrifarium* var. *simplex, Euastrum didelta* var. *bengalicum* Lagerheim and *Triploceras gracile* Bailey. Desmids have also been observed to have altitudinally-defined distributions where Vyverman (1992) demonstrated that northern montane taxa in Papua New Guinea were predominately confined to altitudes of 1700 to 2500 m, higher than other non-cosmopolitan species. This survey was conducted below this designated altitudinal range, and considering the aforementioned tropical desmids encountered, the flora here largely represents a (sub)tropical lowland one, with the possible exceptions of *Staurastrum* cf. *avicula* and *Cosmarium* cf. *difficile* var. *messikommeri*.

A synoptic guide of the desmids encountered during this study

Family Mesotaeniaceae Oltmanns (saccoderm desmids *sensu lato*)

Cylindrocystis Meneghini ex De Bary (1858).

Cylindrocystis brebissonii var. ***minor*** West & G.S.West

Brook and Williamson 2010, p. 30, pl. 3, figs 1–17.

Description: LM: Cells cylindrical, 36.7–47.7 μm, L × 12.7–13.5 μm Br.; chloroplast asteroid-stelloid. **Fig. 14D–F.**

Remarks: Brook and Williamson (2010) note that this species and *Cylindrocystis gracilis* I.Hirn share similar cellular dimensions but can be differentiated based on chloroplast morphology.

Location: Basket Swamp.

Australian Distribution: A new record for New South Wales, previously reported from the Northern Territory and Victoria.

Cylindrocystis cf. ***brebissonii*** var. ***turgida*** Schmidle

Brook and Williamson 2010, p. 30, pl. 4, figs 1–12.

Skinner 1977, p. 56, pl. 4, fig. 3. As *Cylindrocystis* species.

Description: LM: Cells ellipsoid, with stouter forms having one end broader than the other, 52–82 μm in L. by 38.5–47.5 μm Br.; often surrounded by a relatively thick mucilaginous envelope; chloroplasts like that of *C. crassa* de Bary, asteroid with two pyrenoids. **Fig. 15B & C.**

Notes: Skinner (1977) reports of a strikingly similar form as *Cylindrocystis* sp. with dimensions of 55–60 μm in length and 40–45 μm in width and remarks that one side appears more or less flattened in end view. The Australian, New England forms here are distinctly larger than any records of *C. crassa* and broader than any records of *C. brebissonii* var. *turgida* from this country or overseas.

Location: Basket Swamp.

Australian Distribution: Previously recorded from Queensland. A new record for New South Wales, if confirmed.

Cylindrocystis crassa de Bary

Brook and Williamson 2010, p. 31, pl. 5, figs 1–8, pl. 6, fig. 1.

Description: LM: Cell 27.7 μm L. × 20 μm Br.; chloroplast asteroid. **Fig. 15A.**

Notes: Only a few, seldom individuals were observed.

Location: Basket Swamp.

Australian Distribution: Previously reported from New South Wales and Queensland.

Cylindrocystis cushleckae A.J.Brook

Brook and Williamson 2010, p. 32, pl. 9, figs 1–15; pl. 10, figs 1–17.

Description: LM: Cells cylindrical, 7.1–8.5 μm, L × 15.4–32.4 μm Br.; chloroplast axile-stelloid type with one to two irregularly dissected longitudinal lamellae seen in face view. **Fig. 14A–C.**

Notes: This was the most commonly encountered species; it was present in almost all samples and was often the sole species collected from terrestrial cushions of *Sphagnum*.

Locations: Basket Swamp, New England National Park and Oakey Creek.

Australian Distribution: A new record for Australia.

Cylindrocystis gracilis I.Hirn

Brook and Williamson 2010, p. 34, pl. 12, figs 1–16.

Description: LM: Cells cylindrical, 29.2–31.8 μm L × 13.4–14.7 μm Br.; Chloroplast axile-stelloid with one to two longitudinal ridges in face view. **Fig. 14G.**

Locations: New England National Park and Oakey Creek.

Australian Distribution: A new record for Australia.

Mesotaenium Nägeli (1849).

Mesotaenium endlicherianum Nägeli

Brook and Williamson 2010, p. 86, pl. 39, figs 1–21.

Description: LM: Cells elliptical in outline, 14.1–34.7 µm L × 9.9–12 µm Br; L:B 1.3–2.9; chloroplast a parietal cup. **Fig. 14I.**

Location: Basket Swamp.

Australian Distribution: A new record for Australia.

Mesotaenium macrococcum (Kützing) Roy & Bisset

Brook and Williamson 2010, p. 86, pl. 37. figs 1–7; pl. 38, figs 1–8 & 11.

Description: LM: Cells oval in outline, 24.7–41 µm, L × 10.1–13.9 µm Br; L:B 2.3–3; chloroplast an axile plate with a centrally positioned *pyrenoid*. **Fig. 14H.**

Notes: Brook and Williamson (2010) note this species forming mucilaginous masses; we only encountered single cells or colonies of four.

Locations: New England National Park and Oakey Creek.

Australian Distribution: A new record for New South Wales; reported previously from Victoria.

Netrium (Nägeli) Itzigsohn & Rothe in Rabenhorst (1856).

Netrium digitus (Brébisson ex Ralfs) Itzigsohn & Rothe complex

Brook & Williamson 2010, p. 53, pl. 15, figs 1¬–4; pl. 16, figs 6–7; pl. 18 figs 1 & 3.

Description: LM: Cells relatively large, 129–227 µm L × 35.7–62 µm Br. **Fig. 15D.**

Notes: Based on a comprehensive study by Ohtani (1990), the cell size of this complex is highly variable and interlink with similar species and infraspecific taxa in this genus. *Netrium digitus* var. *lamellosum* (Brébisson ex Kützing) Grönblad was incidentally encountered with *N. digitus* var. *digitus* and have been treated here synonymously like that of Brook and Williamson (2010) and as well as Coesel & Meesters (2007). Additionally, while both Brook and Williamson (2010) and Ohtani (1990) agree that *Netrium naegelii* (Brébisson ex W.Archer) West is a distinct species from *N. digitus*, some of the cells we encountered had the chloroplast in too poor condition to confirm if this species was also present. To add further confusion, Ohtani (1990) states that *N. naegelii* possess apical vacuoles, whereas Brook and Williamson (2010) never encountered any specimens from Britain that they regarded as *N. naegelii* with this feature. We also did not encounter any individuals of *Netrium* with vacuoles.

Locations: Basket Swamp and Ebor Common.

Australian Distribution: Both *Netrium digitus* var. digitus and *Netrium digitus* var. *lamellosum* have been reported previously from the Northern Territory, Queensland and New South Wales. *Netrium digitus* has also been recorded from Victoria and Tasmania. *Netrium naegelii* has been reported from the Northern Territory and South Australia.

Spirotaenia Brébisson in Ralfs (1848).

Spirotaenia condensata Brébisson

Croasdale & Flint 1986, p. 33, pl. 1, figs 11, 12.

Description: LM: Cells cigar-shaped, 104–124 µm L. × 18.2–19.7 µm Br.; chloroplast parietal, as a broad, spiralling band. **Fig. 13 F.**

Location: Ebor common.

Australian Distribution: Previously reported from N.S.W. Also reported from the Northern Territory and Victoria.

Spirotaenia sp.

Description: LM: Cells fusiform, 35.5–36.6 µm L. × 8.2–8.4 µm Br.; chloroplast parietal, forming a spiral.

Notes: Only a pair of cells post asexual division within a mucilaginous sheath was encountered. While the cell shape and a ribbon-like chloroplast could be discerned, they had deformed from the preservation process and identification to level of species was not possible.

Location: Ebor common.

Tortitaenia Brook (1998).

Tortitaenia obscura (Ralfs) Brook

Brook & Williamson 2010, p. 111, pl. 50, figs 1–11.

Basionym: *Spirotaenia obscura* Ralfs

Synonym: *Polytaenia obscura* (Ralfs) Brook *nom. illeg.*

Description: LM: Cells fusiform to almost cigar-shaped. **Fig. 15E.**

Notes: Only two cells post asexual division encountered from live culture.

Location: Ebor Common.

Australian Distribution: Previously reported from New South Wales on numerous occasions.

Family Peniaceae Haeckel 1894 (placoderm desmids *pro parte*)

Penium Brébisson ex Ralfs (1848).

Penium exiguum W.West

Brook & Williamson 2010, p. 139, pl. 62, figs 1–7.

Description: LM: Cell cylindrical 37.2–58 µm L. × 7.4–8.5 µm Br.; Ap. 7.1–8.6 µm, slightly dilated; I. 6.4–7.7 µm. *Cell wall* granular with girdle bands. Chloroplasts axile-stelloid with longitudinal ridges. **Fig. 15F.**

Location: Basket Swamp.

Australian distribution: A new record for Australia.

Family Closteriaceae A.Pritch. (placoderm desmids *pro parte*)

Closterium Nitzsch ex Ralfs (1848).

Closterium abruptum var. ***brevius*** (West & G.S.West) West & G.S.West

West & West 1904, p. 160, pl. 20, figs 11, 12.

Description: LM: Cells curved 83–110°, 77–123 µm L. × 10.2–19.5 µm Br., with an L:B of 4.8–8.1; Ap. 4.3–5.3 µm. *Cell wall* smooth, girdle bands present. Chloroplasts axile with one to two longitudinal ridges and one to three pyrenoids. Terminal vacuole typically bearing a single crystal, but up to two observed. **Fig. 8B.**

Notes: Brook and Williamson (2010) regard *Closterium abruptum* var. *brevius* as "invalid" based on previous population studies where the varieties could not be separated into distinct morphological groups. They also note this species as an acidophile, being frequently found amongst *Sphagnum*.

Location: Basket Swamp and Ebor Common.

Australian distribution: In his census of the freshwater algae of New South Wales, Playfair (1917) recorded this species but no voucher were reported.

Closterium cf. ***calosporum*** Wittrock

Ling and Tyler 2000, p. 135, pl. 61, fig. 1.

Description: LM: Cells curved 93–113°, 75–93 µm in L. × 7.7–9.1 µm Br., with an L:B of 9.7 to 11.2; Ap. 2.3 to 2.8 µm. Chloroplasts having 3–4 pyrenoids along the centre. Apices obliquely truncate with an apical pore. **Fig. 8C.**

Notes: The curvature and dimensions match those in Ling and Tyler (2000) under this name. However, the curvature of the cells are more like *Closterium dianae* Ehrenberg ex Ralfs, which Brook and Williamson

(2010) mention can be confused with this species but the dimensions recorded here are well below for this species and any of its varieties. This species can be confused with forms of *Closterium venus* Kützing ex Ralfs and *Closterium parvulum* Nägeli whereby complete certainty can only be achieved by observations of the characteristic zygospores (Brook and Williamson 2010).

Locations: Basket Swamp, Ebor Common and New England National Park.

Australian distribution: Reported from the Northern Territory, Queensland, New South Wales, Victoria and Western Australia.

Closterium closterioides (Ralfs) A.Louis & Peeters

Basionym: *Penium closterioides* Ralfs

Synonym: *Closterium libellula* G.W.Fock ex Nordstedt

Croasdale & Flint 1986, 54, pl. 4, figs 7, 8.

Description: LM: Cells cylindrical, sides distinctly parallel to one another. Ap. 8–12.6 µm, L. 190–321 µm, Br. 29.5–32.9 µm. **Fig. 9F.**

Notes: Commonly found in *Sphagnum* pools (Croasdale & Flint 1986).

Location: Basket Swamp.

Australian distribution: Recorded from Queensland**,** New South Wales and Victoria under its various synonyms.

Closterium closterioides var. ***intermedium*** (Roy & Bisset) Růžička

Croasdale & Flint 1986, 55, pl. 4, figs 11, 12.

Description: Cells straight, broadly fusiform, 85–131 µm L. × 15.1–25.7 µm Br., with an L:B of 5.1–5.7. **Fig. 8E.**

Notes: Associated with *Sphagnum* as typical variety (Croasdale & Flint 1986).

Locations: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory and New South Wales.

Closterium cynthia De Not.

Coesel and Meesters 2007, p. 42, pl. 16, fig. 3.

Description: LM: Cells strongly curved 81–128°, with median portion often straight, 131–185 µm L. × 13.6–19.7 µm Br. with a L:Br of 8.6–10; Ap. 4.65–6 µm. Cell wall striate with girdle bands. Chloroplast with three to seven axile pyrenoids. **Fig. 8D.**

Notes: Brook and Williamson (2010) transferred this species to *Closterium jenneri* forma *cynthia*.

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, New South Wales, Victoria and Tasmania

Closterium dianae var. ***arcuatum*** (Brébisson ex Ralfs) Rabenhorst

Brook and Williamson 2010, p. 283, pl. 132, fig. 4.

Description: LM: Cells strongly curved, greater than 115°, 243–272 µm L. × 16.1–17.1 µm Br. Ap. 1.7–2.6 µm. Chloroplasts axile, with five to six pyrenoids. Terminal vacuole containing a single crystal, end pore present. **Fig. 8A.**

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, South Australia, Tasmania and New South Wales.

Closterium gracile Brébisson ex Ralfs

Brook and Williamson 2010, p. 185, pl. 75, figs 1–13.

Description: LM: Cells 182–200 µm L. × 2.97–3.95 µm Br. **Fig. 9D.**

Notes: This cosmopolitan species is essentially an acidophile and often found in abundance in *Sphagnum* bogs and peaty pools (Brook & Williamson 2010).

Location: Basket Swamp, New England National Park.

Australian distribution: Encountered previously from all Australian mainland states and territories except the Australian Capital Territory.

Closterium kuetzingii var. ***procerum*** Skuja

Croasdale & Flint 1986, p. 62, pl. 11, figs 9, 10.

Description: LM: Cell 235 µm L. × 12.9 µm Br., with an L:B of 18.2 Ap. 2.61 µm. **Fig. 9E.**

Notes: Differs from *Closterium kuetzingii* var. *kuetzingii* Brébisson in that the cells are consistently more slender and stouter (see Croasdale and Flint 1986).

Location: Basket Swamp.

Australian distribution: This species was described from New Zealand and reported for New South Wales (Playfair 1917) and for the Northern Territory from Buffalo Billabong (Thomasson 1986).

Closterium lunula Ralfs

Brook and Williamson 2010, p. 16, pl. 6, figs 1–8.

Description: LM: Cells broadly fusiform, dorsal side slightly curved, 465–550 µm L. × 59–95.2 µm Br. **Fig. 9A**.

Location: Basket Swamp and Ebor Common.

Australian distribution: Reported previously from New South Wales, Victoria and Tasmania.

Closterium navicula (Brébisson) Lütkemüller

Brook and Williamson 2010, p. 167, pl. 67, figs 1–8, 16 & 17.

Description: LM: Cells broadly fusiform, 51–65 µm L. × 14.6–15.2 µm Br., with an L:B of 3.5–4.3. **Fig. 8F.**

Location: Basket Swamp and Ebor Common.

Australian distribution: Reported from all states and territories except South Australia and Western Australia.

Closterium ralfsii var. ***hybridum*** Rabenhorst

Brook & Williamson 2010, p. 298, pl. 141, figs 2–5, 6.

Description: LM: Cell curved 34°, Ap. 5.1–5.9, 480 µm L., 30.3–30.4 µm Br. Wall finely striate, over 10 per 10 µm. **Fig. 9B.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales, seen previously in the Northern Territory.

Closterium striolatum Ehrenberg ex Ralfs

Brook & Williamson 2010, p. 227, pl. 101, figs 1–5 & pl. 102, fig. 5.

Description: LM: Cells curved 70–75°, 185–270 µm in L. × 21.9–29.4 µm Br., with an L:B of 8.4–12.3; Ap. 8–10 µm. SEM: Striae less than 2 µm apart, circa 1.5 µm; eight per 10 µm. **Fig. 9C.**

Notes: Brook and Williamson (2010) observed punctae between the striae under LM for this species, though we did not detect this feature in our material. They also note that this species is found in a range of acidic habitats, particularly *Sphagnum*.

Location: Basket Swamp.

Australian distribution: Numerous observations of this species have been reported from all the Australian states and territories except for the Australian Capital Territory and Western Australia.

Family Desmidiaceae Ralfs (placoderm desmids *pro parte*)

Actinotaenium (Nägeli) Schellenberg (1897).

Actinotaenium cucurbitinum (Bisset) Teiling

Coesel and Meesters 2007, p. 60, pl. 31, figs 9–10.

Description: Cells broadly fusiform, 56–61 µm L. × 22.8–25.2 µm Br, I. 22.4–23.8 µm. Ap. 12.6–13.7 µm; truncately rounded. Chloroplast stelloid. **Fig. 10A.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales. This species has been reported from the Northern Territory and South Australia.

Actinotaenium diplosporum var. ***americanum*** (West & G.S.West) Teiling

Coesel and Meesters 2007, p. 61, pl. 30, figs 1–2.

Description: Cells cylindrical to slightly ellipsoid, 58–64 µm L. × 23.4–26.8 µm Br, with a L:B of 2.4–2.6. Sinus very small and sharp. Chloroplast asteroid. **Fig. 10B.**

Location: Ebor Common.

Australian distribution: A new varietal record for Australia. The type variety has been reported the Northern Territory and Tasmania.

Actinotaenium cf. ***phymatosporum*** (Nordstedt) Kouwets & Coesel

Coesel and Meesters 2007, p. 62, pl. 30, figs 11–12.

Description: LM: Cells, 27.7–46.5 µm L., 12.3–16.3 µm Br., with a L:B of 11.3–15.9 µm. Chloroplast lobostelloid. SEM: Cell wall striated by a series of fine pores parallel to one another. **Figs 19A, B & C.**

Notes: This species is asexually almost morphologically identical to *Actinotaenium spinospermum* (Joshua) Kouwets & Coesel which tends to be less than 30 µm in length. Certain identification between the two species requires confirmation of the different type of zygospores (Coesel & Meesters 2007), which were not observed in this survey.

Locations: Basket Swamp, Ebor Common and New England National Park.

Australian distribution: Reported previously from New South Wales (Skinner 1979) as *Penium phymatosporum* Nordstedt with zygospores that are depicted as globose and described as irregularly mamillated, suggesting they are more likely to be *A. spinospermum*.

Cosmarium Corda ex Ralfs (1848).

Cosmarium amoenum Ralfs

Croasdale & Flint 1988, p. 51, pl. 55, figs 4,5.

Description: LM: Cells longer than broad, 49–69.5 µm L. × 27–38 µm Br., elliptic in outline; Sinus closed, I. 10.5–18.3 µm. Th. 21.2–26 µm. Cell wall granulate except in some specimens where the central portion was smooth. Chloroplast with two pyrenoids adjacent to one another per semi-cell. SEM: Granules are surrounded by four to six (typically 5) fine pores. Specimens which lack granules from the central area of the cell face (see remarks var. *mediolaeve*) have smaller, less prominent granules; above the isthmus lies one to three rows of granules. Throughout the granule-vacant area are numerous fine pores in a scattered arrangement. **Figs 10C, 20 A–F.**

Notes: *Cosmarium amoenum* var. *mediolaeve* Nordstedt was also encountered and is very similar to the nominate, but in the former granules are smaller and absent from the central portion of the semicell, with only two horizontal rows just above the isthmus. We hypothesise that this variety may be a nascent developmental stage of the species.

Locations: Basket Swamp and Ebor Common.

Australian distribution: *Cosmarium amoenum* has been previously observed in Tasmania, Victoria and New South Wales. *Cosmarium amoenum* var. *mediolaeve* has also been reported from New South Wales and Victoria.

Cosmarium amplum Nordstedt

Croasdale & Flint 1988, p. 51, pl. 51, figs 5, 6.

Description: LM: Cells 128–136 µm L. × 90–97 µm Br, I. 35.6–.38 µm.; 66 µm Th. **Fig. 11C.**

Location: Basket Swamp.

Australian distribution: Queensland, New South Wales and Victoria.

Cosmarium annulatum (Nägeli) De Bary

Croasdale & Flint 1988, p. 53, pl. 55, figs 16–19.

Homotypic synonym: *Penium annulatum* (Nägeli) W.Archer

Description: LM: Cells cylindrical, 44.6–45.7 µm L. × 15.7–18.6 µm Br, I. 13.6–16.6 µm. Four or five transverse series of smooth nodules per semicell were observed. SEM: The nodules are oval-shaped and appear to develop from two granules opposite ends of one another and then combine when mature. The bottom of each nodule adjacent to the isthmus has a minute pore. Between all the transversely arranged nodules are three fine pores. The cell apex has concentric rings of fine pores, otherwise smooth. **Figs 21 A, B, C & D.**

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales as *P. annulatum* (Skinner 1977).

Cosmarium askenasyi Schmidle

Croasdale & Flint 1988, p. 53, pl. 50, figs 10–11.

Description: LM: Cell 167 µm L. × 134 µm Br, I. 62 µm. Semicells pyramidal in shape with about a dozen bluntly-pointed granules on the basal angles. **Fig. 10G.**

Location: Basket Swamp.

Australian distribution: Reported previously from New South Wales.

Cosmarium contractum Kirchner

Croasdale & Flint 1988, p. 61, pl. 33, figs 1 & 2.

Description: LM: Semicells sub-globose, 25–29.7 µm L. × 17.2–19.8 µm Br, I. 5.2–6.8 µm. Chloroplast axile with a centrally placed pyrenoid. SEM: Cell wall finely punctate. **Figs 10J and 22A & B.**

Notes: Individuals of this species with smaller cell sizes (<28 µm long) are sometimes treated as variety *minutum* (Deplonte) Coesel but Croasdale and Flint (1988) suggest such a distinction as artificial. Based on our observations, where cell sizes intergraded between both varieties, we agree that there is no merit in recognition of the variety.

Location: Basket Swamp.

Australian distribution: This species is known from the Northern Territory, New South Wales, Victoria and Tasmania.

Cosmarium cf. ***difficile*** var. ***messikommeri*** (Croasdale) Kouwets

Kouwets 1997, p. 41, figs 69–76.

Description: LM: Cells small, 13.3–17 µm in L. × 8–11 µm Br, with a L:B of 1.47–1.73. I. 2.45–3.18 µm with a Thickness of 7.5–7.7 µm. SEM: Cell wall alveolate, three transversal rows of puncta are located near the apex, centre and base of the semicell. **Figs 23C & D.**

Notes: The overall cell shape and the arrangement of the transversal pores affiliates this *Cosmarium* with the "*difficile*-gruppe" but is considerably smaller than the nominate variety and most of its other varieties or formae. Of the few subspecific forms, which have similar dimensions, such as *Cosmarium difficile* f. *rectangulum* D.B.Williamson and *Cosmarium Difficile* f. *minor* Bourelly, there are consistent differences. For *C. difficile* f. *rectangulum*, which was originally described by Williamson (1994) associated with *Sphagnum* from Britain, it has a much longer L:B ratio of two or more with the sides parallel to one another *i.e.* rectangular semicells. Specimens assigned here are also similar to *C. difficile* f. *minor*—originally described from Madagascar by Bourrelly in Bourrelly & Manguin (1949) as *C. difficile* var. *dilatatum* f. *minor*—possessing lateral margins markedly dilated with an inflated apex. The cell dimensions are also similar to a form listed as *C. difficile* forma by Grönblad et al. (1958), but more rectangular in outline with slightly indented lateral margins. Hirano (1957) describes a small *C. difficile* var. *sublaeve* Lütkemüller, which has a flattened apex and with the sides almost parallel but again is slightly larger and more rectangular than the cells observed here. *Cosmarium difficile* var. *minutissimae* (Woloszynska) Brook is possibly a synonym for *C. woloszynskae* see (Coesel and Meesters 2004), which is a larger desmid with undulating margins. The specimens observed here probably best match *C. difficle* var. *messikommeri*, however, this variety has a putative arctic-alpine

distribution and the dimensions here are slightly below those previously quoted. Kouwets (1997) also notes that this species exhibits thickening of the lateral angles; this was not observed in our specimens.

Location: Ebor Common.

Australian distribution: A new record for Australia, if confirmed.

Cosmarium cf. ***difficillimum*** Playfair

Playfair 1908, p. 614, pl. 13, fig. 5.

Description: LM: Cells 33.4–35.5 µm in L. × 19.4–22.3 µm Br, with a L:B of 1.5–1.6. I. 4.8–5.5 µm with a Th. of 13.5 µm. Cell wall smooth with 3 transversal rows of pore fields. Semicells sub-quadrate with rounded angles, the apex of each bears a depression which appears to be closely arranged pores of at most 3. Chloroplast with a centrally positioned pyrenoid. **Figs 10F and 23A & B.**

Notes: This species is regarded by some as synonymous with *Cosmarium difficile* Lütkemüller but, as Playfair (1908) notes, the cell outline and pore arrangement are quite different. It is most similar to the variety *C. difficile* var. *dilatatum* Borge but that species has the lateral sides broadest near the apex whereas, in *C. difficillimum*, the lateral margins are more or less parallel to one another. In Van Westen (2015), a description of *C. pseudodifficile* M.Van Westen is also similar but that species has lateral margins that are more rounded and distinctly broadest at the centre. For cell outline and size, it is also similar to what Nordstedt (1888) described, and illustrated, as a slightly larger form ('*forma paullo majus*') of *Cosmarium exiguum* W.Archer, but his description is extremely terse, lacking any mention of additional features such as pores.

Location: Basket Swamp.

Australian distribution: Originally described by Playfair *l.c.* from New South Wales.

Cosmarium dorsitruncatum (Nordstedt) G.S. West

Croasdale & Flint 1988, p. 65, pl. 33, fig. 20.

Description: SEM: Cell broader than long with a relatively flat apex; L. 32 µm and Br. 38.7 µm. Sinus deep and closed, I. 13.7 µm. Cell wall finely punctate. **Figs 10K and 22C & D.**

Location: Basket Swamp.

Australian distribution: Recently reported from New South Wales by Dingley (2001) and reported previously from Victoria (West 1909).

Cosmarium margaritiferum f. ***regularius*** (Nordstedt) West & G.S.West

Croasdale & Flint 1988, p. 74, pl. 45, figs 13–14; pl. 46, figs 1–3.

Description: LM: Cells 47.7–54.6 µm L. × 35.5–43.2 µm Br.; L:B of 1.3, I. 12.4–15.4 µm; 26.1–26.2 µm Th. Semicells truncate-pyramidal with rounded angles and a broad flat apex. Cell wall granulate. SEM: Granules are uniform in size and are arranged over the entire surface of the cell except for the middle portion of the semicell face which has larger, more rounded granules (that increase in size towards the centre) and are surrounded by five to six scrobiculations arranged in a hexagonal pattern. **Figs 10H and 24A, B, C & D.**

Notes: *Cosmarium margaritiferum* forma *regularius* is slightly smaller, more elongate compared to the type form with many workers stating that the two forms intergrade. The typical form is commonly found amongst plants and especially *Sphagnum* (see Croasdale and Flint 1988).

Location: Basket Swamp.

Australian distribution: *Cosmarium margaritiferum* Eichwald was recently discovered by Dingley (2001) in New South Wales and has also been reported from Victoria and Tasmania. Dingley (2002) has also reported the forma *regularius* from New South Wales, however, the specimens were smaller than hitherto reported and the central granules were the same size as the rest of the cell wall granules suggesting a possible misapplication for another *Cosmarium* species. *Cosmarium margaritiferum* has been reported from the Northern Territory by Thomasson (1986).

Cosmarium obsoletum var. ***sitvense*** Gutwinski

Croasdale & Flint 1989, p. 81, pl. 29, figs 6,7.

Description: LM: Cell sub-circular, 60 µm L. × 65 µm Br, I. 34.8 µm. Semicells with pore-bearing basal angles. Chloroplast in each semicell has two pyrenoids. **Fig. 10L.**

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, Queensland, New South Wales and Victoria.

Cosmarium phymatodeum A.Kenins, *sp. nov.*

Type: NEW SOUTH WALES: Northern Tablelands: Boonoo Boonoo, Basket Swamp National Park, 8 April 2018, *A.Kenins* 5 (holo: NSW; iso: NE), deposited as permanent slides from a formalin preserved sample, the selected specimens are circled with red ink and represented by Fig. 4A.

Diagnosis: Similar to other species of *Cosmarium* that possess verrucose margins and facial ornamentation but differs from them by lacking a distinct region of smooth cell wall between the submarginal verrucae and central ornamentation; and by the arrangement and number (16–26) of the interconnected facial verrucae.

Description: Cells longer than broad, sub-pyramidal to sub-circular, L. 42.6–53.5 µm, Br. 37.3–42.3 µm, I. 13.6–14.9 µm, Th. 25 µm; cell-margin verrucose, with rows of dentate, intramarginal verrucae. Verrucae are trifid at the cell margin but decrease in size and are at most bifid when closer to the central ornament. Facial verrucae in the centre globular, ranging from 16 to 26 per semicell and interconnected by ridges. Chloroplast with two pyrenoids per semicell. Zygospore unknown.

Additional Figures and Material: Fig. 4B, Fig. 5 A, B, C & D. Other material containing this taxon has been deposited at **NE.**

Distribution and ecology: Thus far only known from Basket Swamp, New South Wales, and associated with *Sphagnum* (pH 5.60).

Etymology: The species epithet is latinised from the Greek 'phymatōdes,' meaning 'warty' or 'verrucose'.

Notes: *Cosmarium phymatodeum* shares its morphological affinities with many species of *Cosmarium* that possess verrucose margins and facial ornamentation, like, *C. quadrifarium*, *C. binum*, *C. subspeciosum*, and their subspecific forms. The lack of smooth cell wall between the marginal verrucae and the facial ornamentation, along with the overall arrangement and number of interconnected facial verrucae is unique to *C. phymatodeum* when compared with the previously mentioned species complexes.

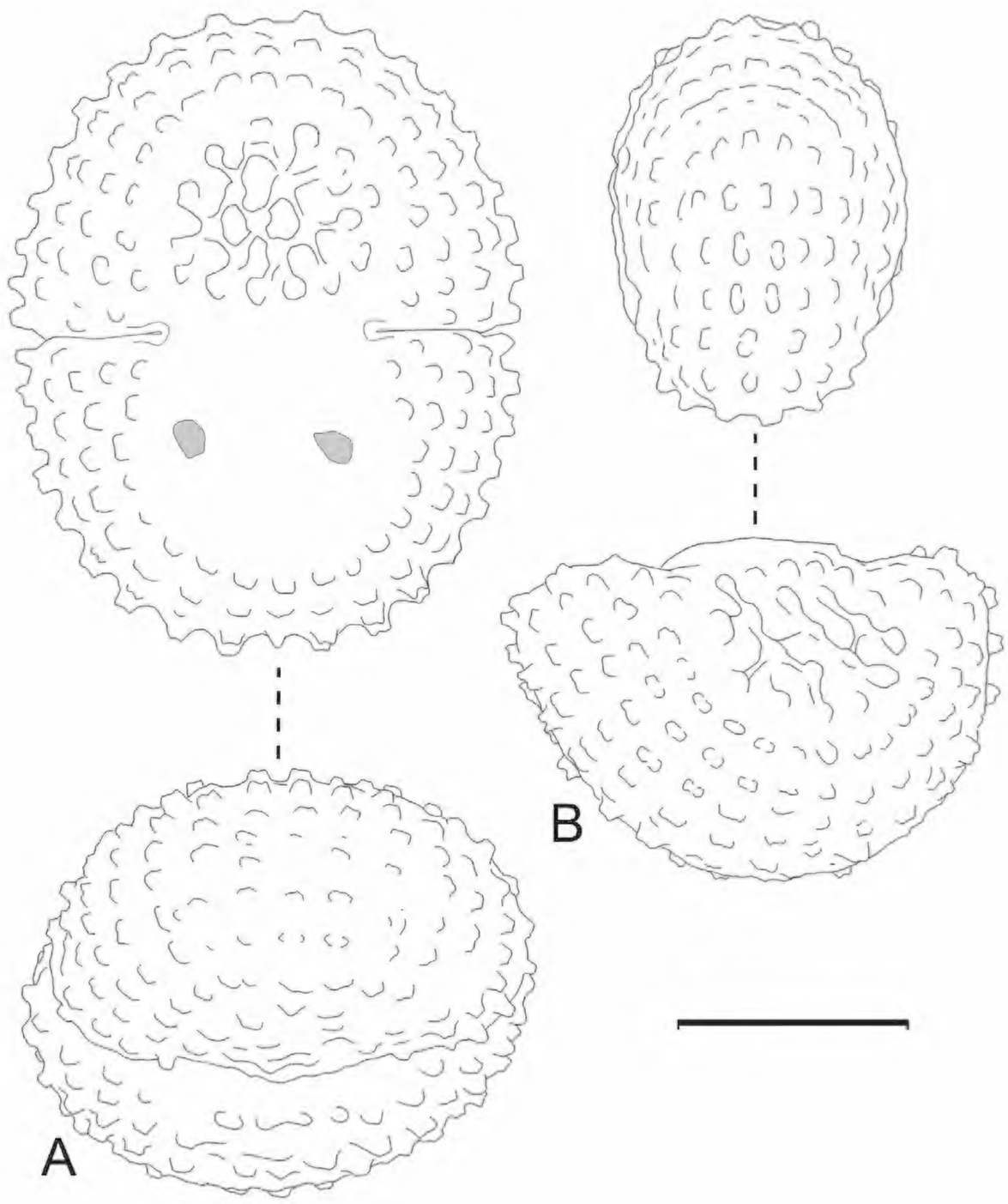

Fig. 4. Line drawing of *Cosmarium phymatodeum*, **A.** whole cell in front view (shaded regions in lower semicell indicate position of pyrenoids) and apical view, **B.** semicell in side- and slightly oblique-view. Scale bar = 20 µm.

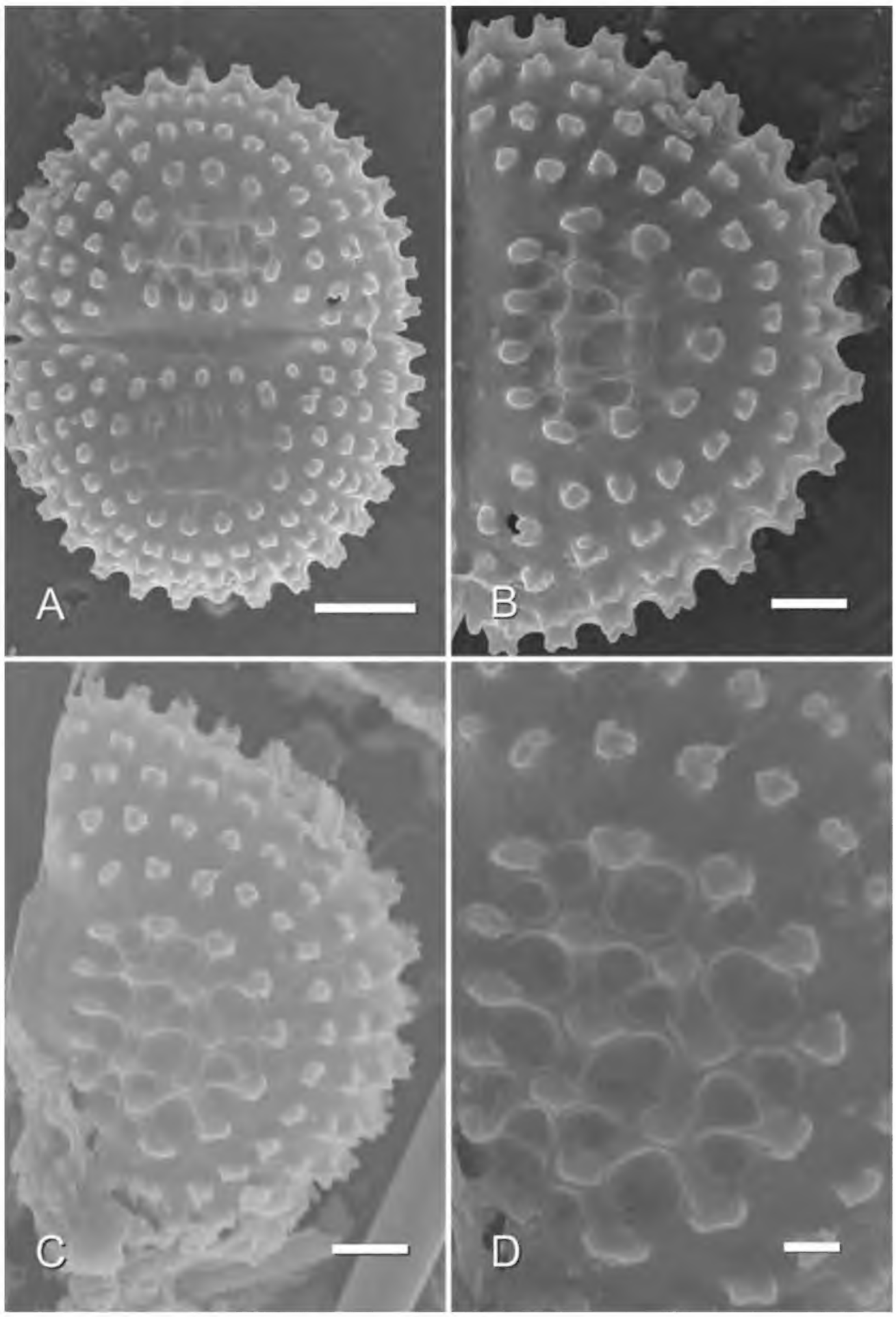

Fig. 5. Scanning electron micrographs of desmids, **A**, **B**, **C** & **D.** *Cosmarium phymatodeum* Scale bar A = 10 µm; B & C = 5 µm; D = 2 µm.

Cosmarium quadrifarium var. ***simplex*** Krieger

Krieger 1932, p. 184, pl. 12, fig. 12.

Description: Cells semicircular, 36.1–57 µm L. × 26.2–43.6 µm Br, I. 11.9–17.4 µm and Th. 18.8–26.8 µm. Margins verrucose with three rows of intramarginal verrucae. Central crown of granules ranged from five to eight. The submarginal verrucae decrease in size and complexity; the smallest are found closest to the central ornament and are at most tridentate with the verrucae not always combining which can occasionally give a false impression of an additional row of submarginal verrucae. The next row of verrucae are larger and generally quadri-dentate with some being tridentate. The final row of verrucae are the largest and quadri-dentate. The central crown of granules are rounded and arranged with five encircling the perimeter of a more or less spherical cavity that is between (5–5.5um) in diameter; each of these granules have a bridge connecting to one central granule. One specimen was observed to have six surrounding a spherical cavity 3–3.5 µm in diameter devoid of a central granule and connecting bridges. **Figs 10D and 27A, B, C, D, E, F.**

Notes: The material observed here best match that of Krieger's var. *simplex* in that they share the reduced number of central verrucae. Krieger *l.c.* states that this variety usually has three to four central verrucae per semicell but also depicts up to seven arranged elliptically. While the number of verrucae here is within this range they differ in their arrangement. Other differences such as the marginal verrucae cannot be compared since Krieger *l.c.* only states that this variety is essentially like the type in all other aspects and the illustrations provide no more detail. Bourrelly & Coute (1991) describe and depict *C. quadrifarium* var. *simplex* from

Madagascar with a more similar central ornamentation, having a crown of five or six verrucae surrounding a central one. This central ornamentation was sometimes observed to be reduced to only four verrucae from the Madagascan material; which connects it to the original description by Krieger.

Locations: Basket Swamp and Ebor Common.

Australian distribution: New varietal record for Australia.

Cosmarium regnellii Wille

Croasdale & Flint 1988, p. 98, pl. 4, figs 1–4,9.

Description: LM: Cells small, hexagonal in outline, L. 10.1–20.3 µm, Br. 10.3–19.8 µm. Sinus linear, closed I. 3.7–5.9. SEM: Cell wall composed of aveoles randomly distributed giving a reticulate appearance. Fine pores distributed about 1 µm from one another. **Figs 11B and 28A, B, C & D.**

Notes: Of the few cells observed, the size dimensions best fit with *Cosmarium regnellii* var. *minimum* Eichler & Gutwinski. Coesel and Meesters (2007) regard the morphology of this species to be highly variable and consider the several varieties of this species to have no taxonomic significance.

Location: Basket Swamp.

Australian distribution: Reported previously from New South Wales and Queensland.

Cosmarium cf. ***reniforme*** var. ***compressum*** Nordstedt

Croasdale & Flint 1989, p. 100, pl. 44, figs 6,7.

Description: LM: Cells 59–73 µm L. × 46.5–65 µm Br, I. 11.9–20 µm.; in apical view oblong, Th. 34.1–36.6 µm Semicells sub-reniforme with a flattened apex. Cell wall entirely granulate except for isthmal region. Chloroplast in each semicell has two pyrenoids, one situated near each lateral lobe. SEM: The cell wall granules are arranged in longitudinal rows (not horizontal) and are surrounded by puncta that are hexagonal in arrangement. **Figs 11A and 26A & B.**

Notes: These specimens have been tentatively designated as *C. reniforme* var. *compressum* since they are larger and have a consistently more open sinus. They should also be compared to the poorly described *Cosmarium reniforme* var. *apertum* West & G.S.West, which has a more open sinus, see West & West (1908).

Location: Basket Swamp.

Australian distribution: Reported from the Northern Territory, Queensland and New South Wales based on previous workers.

Cosmarium spirale (Playfair) Krieger & Gerloff

Playfair 1908, p. 618, pl. 13, fig. 20.

Basionym: *Cosmarium stenonotum* var. *spirale* Playfair

Homotypic Synonym: *Cosmarium pseudopyramidatum* var. *spirale* (Playfair) Playfair

Description: LM: Cells longer than broad, 57 µm L. × 30.1–34.2 µm Br. Sinus closed, linear; I. 7.6–7.9 µm. Semicells pyramidal in outline, wall coarsely scrobiculate. Torsional asymmetry at the isthmus variable. **Fig. 10I.**

Location: Basket Swamp.

Australian distribution: In Australia, only known from New South Wales, but has also been recorded from Papua New Guinea by Thomasson (1967).

Cosmarium subadoxum Grönblad

Coesel & Meesters 2007, p. 142, pl. 61, figs 35,36.

Description: Cells almost as broad as long, 7.9–8.6 µm L. × 7.7–8.4 µm Br. Sinus closed, linear; I. 1.9–2.5 µm. Th. 4.4–4.6 µm from side view (without tubercule). Apex retuse, upper lateral sides convex. Under SEM the cell wall is reticulate-foveate above and below the centrally-placed papilla, the aveoles are arranged in longitudinal rows elsewhere. **Figs 26 C & D.**

Notes: Anissimova (2015) has previously observed the alveolate disposition of the cell wall of this species from Russian material. The ultrastructural sculpturing of the cell wall is also similar to that of *Cosmarium polygonum* (Nägeli) W.Archer in Vyverman (1991) but that species is larger, and the upper portion of the lateral margins are concave.

Location: Basket Swamp.

Australian distribution: A new record for Australia.

Cosmarium striolatum var. ***nordstedtii*** (Möbius) Krieger

Claassen & Eicker 1985, p. 230, figs 29–42.

Basionym: *Pleurotaeniopsis tesselatum* f. *nordstedtii* Möbius

Heterotypic synonyms: *Cosmarium glyptodermum* West & G.S.West

Cosmarium glyptodermum var. *tuberculatum* A.M.Scott & Prescott

Description: LM: Semicells sub-globose, 88–102 µm L. × 53–62 µm Br, I. 32.3–49.9 µm and Th. 53–59 µm. Cell wall granulate, with six conspicuous pores surrounding each of these granules. Due to cell wall architecture obscuring a clear view, chloroplast morphology difficult to determine but appeared to be parietal. SEM: Granules are surrounded by six pits that from lower magnification appear smoothly triangular with a spherical base when examined closer. Each pit possesses a central pore, however, the row of pits that are directly adjacent to the isthmus sometimes had two or three pores. The apex has a region devoid of granules simply composed of pits closely arranged to one another. Both Dingley (2004) and Skinner (1977) have encountered this species in conjugation, with the resultant zygospores spherical and furnished with relatively short and stout spines. **Figs 25A, B, C & D.**

Notes: The cell wall ultrastructure of this species has been previously studied by Claassen & Eicker (1985), where they considered *C. glyptodermum* West & G.S.West and *C. glyptodermum* var. *tuberculatum* as heterotypic synonyms. Conversely, Coesel (2002) regarded *C. striolatum* var. *nordstedtii* (which was originally described from Australia) and *C. glyptodermum* (which was originally described from Africa), as separate 'species' based on morphological and geographical criteria.

The cell wall of the African specimens designated as this name by Claassen & Eicker (1985) are structurally similar to those in our material. However, they mention the cell wall granules are occasionally surrounded by five or seven pits, a feature not observed in this study. Additionally, the overall cell outline of our specimens differ by being more rounded and less conical towards the apex than theirs. Since *P. tesselatum* f. *nordstedtii* was originally described from Queensland and antedates all other supposed synonyms suggested by Claassen & Eicker (1985), we have treated all records pertaining to this taxon in Australia as conspecific. Whether the entities from Africa are indeed a separate species (*C. glyptodermum sensu stricto*) as proposed by Coesel (2002) needs further investigation.

Location: Basket Swamp.

Australian distribution: Originally described from Queensland (Möbius 1892). Playfair (1908) observed this species in great abundance from a coastal *Sphagnum* bog in Coogee, Sydney, New South Wales under the objective synonym *Cosmarium glyptodermum*. Skinner (1979) also reported this species from a swamp near Baldersleigh, New South Wales. This entity has also been recorded from the Northern Territory by Dingley (2004); Ling and Tyler (1986); Scott and Prescott (1958) if all synonyms are accepted.

Cosmarium cf. ***neapolitanum*** var. ***australicum*** Schmidle

Schmidle 1896, p. 308, pl. 9, fig. 10.

Description: SEM: Cell 41.3 µm L. × 50.6 µm Br, I. 11.6 µm. **Fig. 19D.**

Notes: Only a single, slightly distorted cell was encountered during SEM analysis; more specimens are needed to confirm its identity.

Locations: Basket Swamp

Cosmarium cf. ***zonatum*** var. ***compressum*** (Schmidle) Krieger & Gerloff

Krieger & Gerloff 1969, p. 254, pl. 43a, fig. 26.

Description: LM: Cells 27.1–36 µm L. × 15.7–20.7 µm Br, I. 3.85–5.9 µm; Th. 10.6–10.7. **Fig. 10E.**

Notes: The cell outline of our specimens are most similar to those found in the *Cosmarium* "*zonatum*-group", most notably *Cosmarium zonatum* var. *compressum* (Schmidle) Krieger & Gerloff. However, the cells here are slightly stouter compared to the original dimensions for this variety. Confirmation that the arrangement of the transverse pores match the original illustrations with the specimens here is also needed.

Location: Basket Swamp.

Docidium Brébisson ex Ralfs (1848).

Docidium baculum Ralfs

Coesel & Meesters 2007, p. 65, pl. 32, figs 3,4.

Description: LM: Cell 183 µm L, basal swelling 9.4 µm Br. Ap. 8.4 µm. Chloroplast axile. SEM: A whorl of granule-like plications of 'T' shaped folds encircle the isthmus. Cell wall finely punctate.

Notes: Cell dimensions are in the extreme lower range of this species. **Figs 29A & B.**

Location: Basket Swamp.

Australian distribution: This species has been reported from all Australian States and Territories except for Western Australia and the Australian Capital Territory.

Euastrum Ehrenberg ex Ralfs (1848).

Euastrum ansatum var. ***ansatum*** Ehrenberg ex Ralfs

Prescott et al. 2001, p. 15, pl. 58, figs 6, 6a, 7f, 8.

Description: LM: Cells 84–87 µm L by 35.8–38.3 µm Br.; I. 12.1–14.1 µm, Ap. 18.1–19.3 µm. Polar lobes slightly coarsely punctate with the remainder of cell wall smooth. **Fig. 11G.**

Notes: Compare with *Euastrum ansatum* var. *dideltiforme* F. Ducellier and *Euastrum cuneatum* var. *subansatum* R. Boldt.

Location: Ebor Common.

Australian distribution: This species has been reported in most of the Australian states and territories – Northern Territory, Queensland, New South Wales, Victoria and Tasmania.

Euastrum ansatum var. ***simplex*** Ducellier

Prescott et al. 2001, p. 19, pl. 59, figs 3, 4; pl. 60, fig. 2.

Description: LM: Cells 60–67 µm L by 29.3–32.6 µm Br., I. 8.2–10.7 µm, Ap. 16–16.7 µm. On rare occasions the swelling above the basal lobe is present. **Fig. 11H.**

Notes: These may simply be nascent forms of the *E. ansatum* encountered supra.

Location: Ebor Common.

Australian distribution: A new record for Australia.

Euastrum cf. ***ansatum*** var. ***triporum*** Krieger

Prescott et al. 2001, p. 19, pl. 59, figs 6, 7a.

Description: LM: Cells 83–89 µm L by 41.6–43.5 µm Br.; I. 10.7–12.1 µm, Ap. 20.6–22.5 µm. Polar and basal lobes coarsely punctate with the remainder of cell wall smooth. Three mucilage pores are in a triangular arrangement on the face of the semicells. SEM: Within the coarse punctae are fine pores, the remainder of the cell wall has these same pores evenly scattered. **Figs 30A, B, C & D.**

Notes: The cell outline is lacking a slight swelling above the basal lobes. This feature matches specimens under the same name recorded by Croasdale & Scott (1976) from the Northern Territory. Our specimens also lacked any discernible facial tumours that this variety reportedly has.

Location: Basket Swamp.

Australian distribution: New record for New South Wales if confirmed. Previously reported from the Northern Territory and Tasmania.

Euastrum denticulatum var. ***quadrifarium*** Krieger

Croasdale and Flint 1986, p. 89, pl. 22, fig. 15.

Description: LM: Cells 7–8 µm L by 4.7–7 µm Br.; I. 14–3.3 µm, Ap. 2 µm. Most of the cell wall coarsely punctate, up to four central mucilage pores evident. **Figs 11D and 29C & D.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales. Recorded from the Northern Territory on several occasions.

Euastrum didelta var. ***bengalicum*** Lagerheim

Croasdale & Flint 1986, p. 90, pl. 18, fig. 2.

Description: Cells 165–179 µm L by 89–91 µm Br. I. 19.9–21.8 µm. Semicells possess central pores, one above the other. Slight inflation above the basal lobe sometimes present. **Fig. 11F.**

Location: Basket Swamp.

Distribution: Previously reported from north-eastern Australia – Northern territory, Queensland and New South Wales.

Euastrum longicolle var. ***australicum*** Playfair

Croasdale & Flint 1986, p. 94, pl. 20, fig. 6.

Description: LM: Cells 141–148 µm in L. 64–65 µm Br., with a L:B of 2.2–2.3; I. 15.7–16.9 µm. Semicells 'guitar-shaped' with a broad base and elongate neck extending into a dilated apex. Above the isthmus is one or two conspicuous mucilage pores surrounded by three protuberances in a triangular arrangement, another two protuberances are adjacent on either side. SEM: Cell wall for the most part homogenous/smooth with fine puncta except for the dilated apex and lateral lobes which are provided with large pore fields. The five facial protuberances can be smooth or scrobiculate. **Figs 31A, B, C & D.**

Notes: Morphologically distinct and stable from the *E. longicolle* var. *longicolle* Nordstedt to possibly warrant elevation to species status.

Location: Basket Swamp.

Australian distribution: Originally described from New South Wales by Playfair (1907) and thus far only reported from this State.

Euastrum cf. ***longicolle*** var. ***australicum*** Playfair

Euastrum longicolle var. *australicum sensu* Skinner 1977, p. 77, pl. 11, fig. 2.

Description: LM: Cell 134–148 µm in L. 66–67.1 µm Br, with a L:B of 2–2.2 I. 17.3–18.5 µm; 58 µm Th. SEM: Ultrastructure like that of *E. longicolle* var. *australicum* described above. **Fig. 32A, B, C & D.**

Notes: A stout form where the neck of the polar lobe is much shorter compared to *E. longicolle* var. *australicum* in the strict sense. Skinner *l.c.* only encountered this short morphological form which may suggest a distinct sibling species, but more specimens should be examined to confirm this since both the typical and stout forms were often encountered together in this study. It is also morphologically similar to *Euastrum bullatum* Playfair concerning the apical lobe, but that species is smaller in dimensions and has more truncated lateral lobes and less facial protuberances. The New England specimens appear to be an intermediate of *E. longicolle* var. *australicum* and *E. bullatum.*

Location: Basket Swamp.

Australian distribution: Thus far solely known from the New England region, New South Wales.

Euastrum cf. ***luetkemuelleri*** var. ***laterepunctatum*** Scott & Prescott

Scott and Prescott 1958, p. 36, fig. 6: 8.

Description: LM: Cell 22.4 µm L by 15.9 µm Br.; I. 5.5 µm, Ap. 10.2 µm; Th. 11.5 µm. In side-view a mucilage pore just below apex and the mid-region of each side of the semicell apparently thickened. **Figs 16C & D.**

Notes: Only a few cells were encountered, more specimens are needed to confirm its identity.

Location: Basket Swamp.

Australian distribution: A possible new record for New South Wales. Originally described from the Northern Territory.

Euastrum neosinuosum var. ***germanicum*** (Raciborski) O.V. Anissimova & M.D. Guiry

Croasdale and Flint 1986, p. 96, pl. 18, fig. 10.

Basionym: *E. sinuosum* f. *germanicum* Raciborski

Description: LM: Cells 77–84 µm L by 42.7–47.7 µm Br.; I. 12.4–13.3 µm, Ap. 20.6–22.5 µm. Most of cell wall coarsely punctate, with up to four central mucilage pores evident. SEM: The coarse puncta are occasionally pitted with a fine pore (rarely two pores). The central mucilage pores are also pitted with a fine pore. **Figs 11E and 33A, B, C & D.**

Notes: The arrangement and number of central mucilage pores completely match those depicted in Playfair (1907) under the basionym *E. sinuosum* f. *germanicum*. Anissimova & Guiry (2021a) have noted that *Euastrum sinuosum* Lenormand ex W.Archer is an illegitimate name and proposed the replacement *Euastrum neosinuosum* O.V.Anissimova & Guiry. Subsequently, Anissimova & Guiry (2021b) have provided the nomenclatural and/or taxonomic changes for subspecific taxa attributed with this name as well.

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales by Playfair (1907).

Groenbladia Teiling (1952).

Groenbladia bourrellyi Coesel

Coesel 1998, p. 111, figs 13–15.

Heterotypic synonym: *Hyalotheca neglecta* var. *major* Taylor

Description: LM: Cells elongate, cylindrical22.8–26.3 µm L. and 10.7–11.6 µm Br. In short filaments of two to five; L:B 2.1–2.3. Chloroplast lamelliform. **Fig. 16A.**

Notes: Coesel (1998) provides an in-depth explanation on this species often being mistakenly assigned to *Groenbladia neglecta* (Raciborski) Teiling.

Location: Basket Swamp.

Australian distribution: A new record for New South Wales; this species has also been observed from the Northern Territory by Ling and Tyler (2000) under the misapplied name *G. neglecta*.

Micrasterias C.Agardh ex Ralfs (1848).

Micrasterias bicoronata A.Kenins, *sp. nov.*

Type: NEW SOUTH WALES: Northern Tablelands: Boonoo Boonoo, Basket Swamp National Park, 8 April 2018, *A.Kenins* 5a (holo: NSW; iso: NE), deposited as permanent slides from a formalin preserved sample, the selected specimens are circled with red ink and represented by Fig. 6A.

Micrasterias tropica var. *indivisa auctt non*. (Nordstedt) Eichler & Raciborski: Skinner in *Proceedings of the Linnean Society of New South Wales* 104: 254, fig. 10a, b (1979).

Diagnosis: Like *Micrasterias tropica* var. *indivisa*, but differs by the possession of two inflations with concentrically arranged verrucae per semicell; and by the shorter apical processes that are parallel to slightly convergent to one another.

Description: Cells 86–93 µm L. (90–120 µm in Skinner *l.c.*) by 71–85 µm Br. (80–90 µm in Skinner *l.c.*). Apex of polar lobe 46.7–54 µm wide, I. 19.3–22.4 µm; Th. Circa 39 µm. Semicells bearing two concentric series of verrucae above the isthmus; the series of verrucae adjacent to the isthmus is often larger and made up of more verrucae compared to the other and is less developed in some specimens. Processes of the apical and lateral lobes spinulate. Zygospores encountered by Skinner *l.c.* as spherical with a diameter of 65–75 µm and having a mixture of simple and bifurcate spines, being randomly distributed, mesospore brown.

Additional Figures and Material: Figs 6B and 12D. Other material containing this taxon has been deposited at **NE.**

Distribution and ecology: Thus far only known to occur in the Northern Tablelands from several sites. Skinner (1979) reported this species from collections at Baldersleigh, near Kingston (with zygospores); Round Mountain; Cooney Creek, near Hillgrove; Bullock Creek, Point Lookout; and Sandy Creek, near the dog-gate, Armidale-Dorrigo Road. Also collected from Basket Swamp (the most northern known site) associated with *Sphagnum* (this study).

Etymology: The species epithet bi – (two) and coronata (crowned) refers to the semicells of this species bearing two circular, concentric series of verrucae that appear like a crown (corona).

Notes: Skinner (1979) previously identified the species in question as *M. tropica* var. *indivisa* but noted that it differs from those described in Tyler (1970) from south-eastern Australia by the possession of not one but two concentrically arranged verrucae. The presence of these two rings of verrucae are consistent from the Northern

Tablelands specimens which differ from this variety in the strict sense occurring in Victoria, Tasmania and as well as New Zealand (from where it was originally described) as only having one. *M. bicoronata* can be further differentiated from *Micrasterias tropica* Nordstedt and the variety *indivisa* in that the apical processes are shorter and are parallel to slightly convergent to one another rather than arising divergently.

Coesel and van Geest (2014) have recently revised many varieties assigned to the *Micrasterias tropica* complex from Africa by elevating them to species status based on morphologically distinct forms with defined geographic distributions. With this in consideration and based on the previous observations by Tyler (1970) and Skinner (1979) combined with this study, this entity warrants species status.

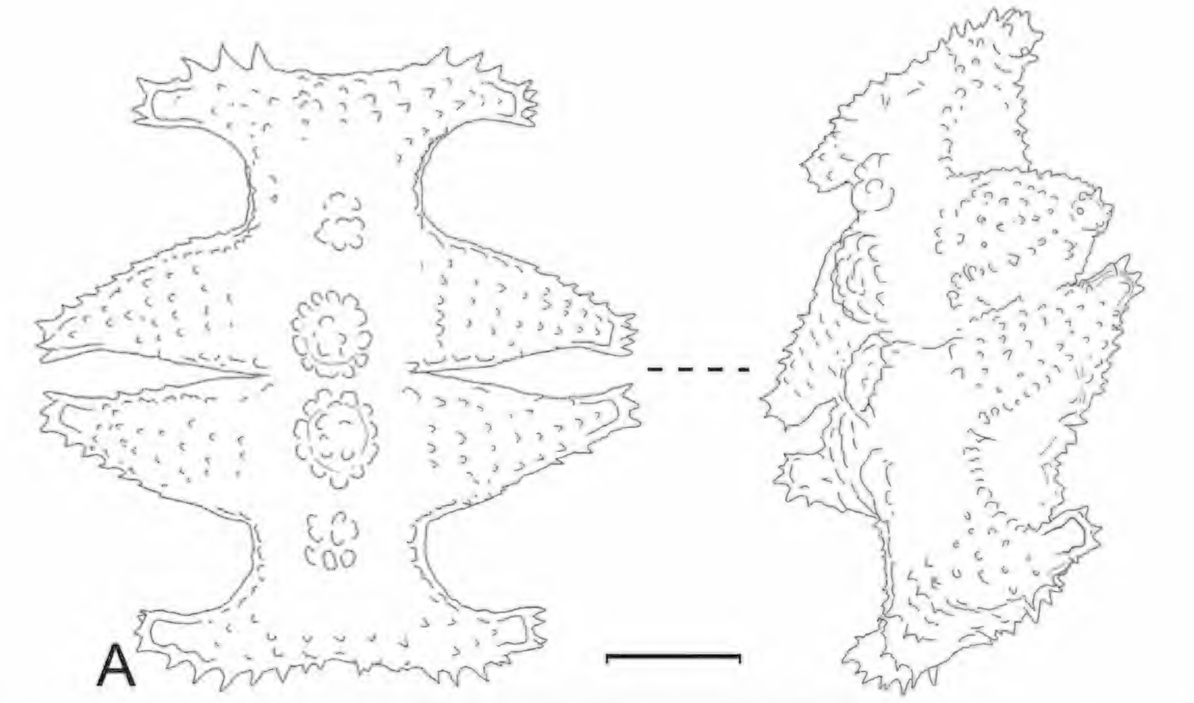

Fig. 6. Line drawings and scanning electron micrograph of *Micrasterias bicoronata*, **A**. front- and slightly oblique side-view. Scale = 20 μm. **B**. semicell. Scale bar = 10 μm.

Micrasterias decemdentata (Nägeli) Archer

Croasdale & Flint 1986, p. 104, pl. 24, figs 5, 9, 10.

Description: Cell 67 μm L. by 70 μm Br., polar lobe 55 μm μm wide, I. 13.4 μm. Lateral lobes bidentate. **Figs 12A and 16B.**

Notes: *Micrasterias zeylanica* F.E. Fritsch is morphologically similar, but that species has the lateral lobes consistently pointed downward see Croasdale and Flint (1986).

Location: Basket Swamp.

Australian distribution: Previously reported from most Australian states and territories – Northern Territory, Queensland, New, South, Wales, Victoria and Tasmania.

Micrasterias jenneri Ralfs

Coesel & Meesters 2007, p. 88, pl. 51, figs 1&2.

Description: Cell 153 μm in L. by 93 μm Br., I. 22.7 μm. **Fig. 12C.**

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales and Victoria.

Micrasterias nordstedtii f. ***australiensis*** Thomasson

Thomasson 1973, p. 386, fig. 1: 1.

Synonym: *Micrasterias* sp. *sensu* Dingley, *Telopea* 9: 607, fig. 6b. (2001).

Description: Cells 308–327 µm L. by 283–299 µm Br., with a L:B of 1.08–1.1. Polar lobe 54–55 µm µm wide, I. 33.5–34.1 µm. Upper and lower lateral lobes of equal size, both of which are divided to the fourth order; one to three (typically two) intramarginal spines present on the outer portion of the major incisions. Basal inflation located above the isthmus and occasionally furnished by a single spine. **Fig. 7.**

Notes: The cells observed here differ slightly from the original description by being broader, having fewer intramarginal spines and possession of a basal inflation furnished with spine positioned above the isthmus. Dingley (2001) reports a very similar specimen which was considered like *M. apiculata* var. *fimbriata* f. *fimbriata* (Ralfs) Nordstedt. All these aforementioned differences appear to be minor and part of the polymorphic variation observed in this poorly known form and have been circumscribed here as referring to the same entity.

The type forma "*nordstedtii*" is so far only known from New Zealand and differs in cell outline and polar lobe ornamentation. It follows, that the Australian records of this form and the New Zealand records of the type forma are probably separate species when considering their differences in morphology and distribution.

Location: Basket Swamp.

Australian distribution: Thomasson (1973) proposed this forma from Cataract reservoir, New South Wales. Dingley's *l.c.* "*Micrasterias* sp." was sampled from Mountain Lagoon, 14 km northeast of Bilpin, New South Wales.

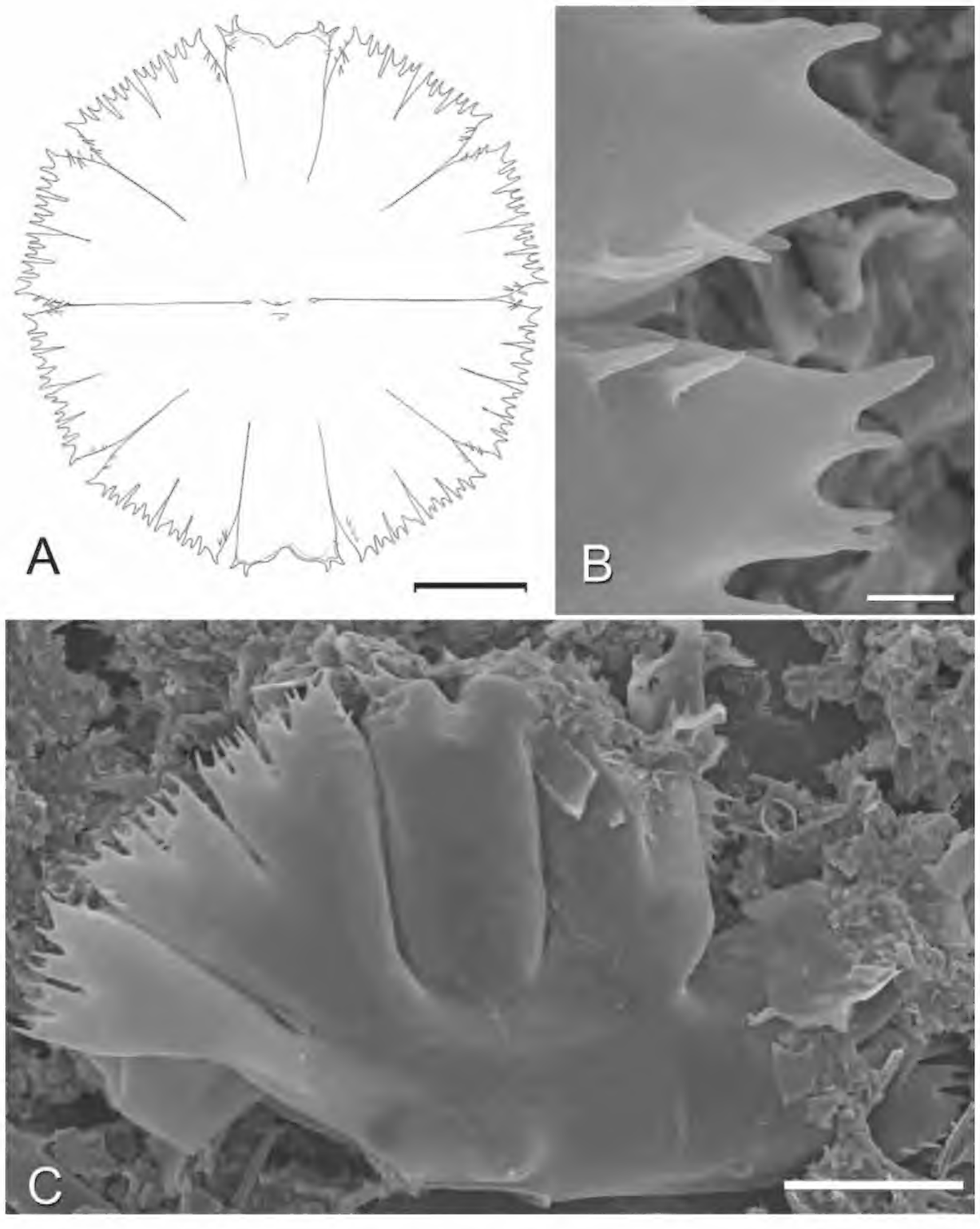

Fig. 7. Line drawing and scanning electron micrographs of *Micrasterias nordstedtii* f. *australiensis*, **A.** entire cell in front-view. Scale bar = 50 µm. **B.** close-up of intramarginal spines. Scale bar = 5 µm. **C.** semicell. Scale bar = 50 µm.

Micrasterias thomasiana var. ***notata*** (Nordstedt) Grönblad

Prescott et al. 2001, p. 191, pl. 137, figs 4–6.

Description: Cells disk-like 226 µm L. × 216 µm Br. **Fig. 12E.**

Notes: Skinner (1979) notes the New England Tableland forms of this species is without much ornamentation. However, the typical three swellings above the isthmus were encountered along with reduced forms in this survey.

Location: Basket Swamp.

Australian distribution: Reported from the Northern Territory, Queensland, New South Wales and Victoria.

Micrasterias truncata var. ***crenata*** (Brébisson) Reinsch

Prescott et al. 2001, p. 198, pl. 100, figs 2, 3.

Basionym: *Micrasterias crenata* Brébisson

Description: Cells disc-like, 72–100 µm L. by 68–90 µm; I. 15.1–23.3 µm. Lateral lobes variable, twice divided but frequently undeveloped (rounded without teeth); typical with teeth also encountered. **Figs 12B and 16E.**

Notes: Various workers have noted the highly polymorphic nature of this species with many of the named forms encountered in the same population. Thus, many of the varieties and forms are regarded as superfluous since they are based on the different stages of development of the lateral lobes. The variety *crenata* was predominant in this survey; the typical variety and the formae *reducta* Prescott were less frequent.

Location: Ebor Common, New England National Park.

Australian distribution: Previously reported from New South Wales and Victoria. *M. truncata* var. *truncata* Brébisson ex Ralfs has been reported from the Northern Territory, New South Wales, Victoria and Tasmania.

Pleurotaenium Nägeli (1849)

Pleurotaenium ehrenbergii (Brébisson) De Bary

Croasdale and Flint 1986, 71, pl. 14, figs 8,16.

Description: LM: Cells elongate, 356–432 µm L. × 26.7–28.7 µm in Br. I. 22.7–23.1 µm and an Ap. of 19.7–22.4 µm crowned with tubercules. Conspicuous basal inflation with at most one smaller swelling. Numerous ribbon-like chloroplasts possessing small pyrenoids along its length. **Figs 34A & B.**

Location: Basket Swamp.

Australian distribution: Recorded from all states except Western Australia.

Pleurotaenium nodosum (F.M.Bailey) Lundell

Croasdale & Flint 1986, p. 73, pl. 14, figs 12, 13.

Description: LM: Cells elongate, 298–311 µm L. × 45.3 µm in Br.; I. 16.8 µm and an Ap. of 26.6 µm crowned with upwardly curving spines. Semicells consisted of 4 undulations. **Figs 34C & D.**

Location: Basket Swamp.

Australian distribution: Reported from the eastern, mainland states Queensland, New South Wales and Victoria.

Pleurotaenium tridentulum (Wolle) W.West

Croasdale & Flint 1986, p. 75, pl. 16, figs 8,9.

Description: LM: Cell baculiform, 260 µm L. × 15.2 µm Br. with an L:B of 17.1; I. 12.6 µm and an Ap. 9.6 µm crowned with four small, short spines. Single undulation after the basal swelling. **Fig. 17A.**

Location: Basket Swamp.

Australian distribution: Previously reported from New South Wales as well as Tasmania.

Staurastrum Meyen ex Ralfs (1848).

Staurastrum aureolatum Playfair *sensu* Thomasson 1972

Thomasson 1972, p. 259, fig. 2: 1–8.

Heterotypic synonym: *Staurastrum digitatum* G.S.West

Description: LM: Cells 22.1–25.7 µm L.csp. × 21.1–26 µm Br.csp; I. 3.56–4.71 µm and often enveloped in a gelatinous sheath. *Processes* obtuse or terminating with two rounded spines. **Figs 18A & B.**

Notes: The specimens here are comparable to those observed by Thomasson (1972) from the plankton of the Rotorua lakes of New Zealand. He designated them as "*Staurastrum brachiatum*-group" and suggested a revision of this complex is needed since most of the forms he encountered intergraded between *S. brachiatum* Ralfs and *S. aureolatum*. The original iconotype of *S. aureolatum* by Playfair (1908) has somewhat dilated process, lacking any terminating spines. Thomasson and Tyler (1971) note that Playfair's illustration is of poor quality. *Staurastrum digitatum* described by West (1909) from Victoria is also considered by some as synonymous with this species see Croasdale et al. (1994).

Location: Basket Swamp.

Australian distribution: This species has been reported from New South Wales and Tasmania as well as Victoria if the synonym *S. digitatum* is also considered.

Staurastrum cf. ***avicula*** Brébisson in Ralfs

Croasdale et al. 1994, p. 84, pl. 84, figs 1–9.

Description: LM: Cell triradiate, L. 17.8 µm, Br. 23.9 µm; I. 6.6 µm. Angles terminating into to two spines. Cell wall granular. **Fig. 17B.**

Notes: A catch-all species, more specimens need to be observed to confirm its identity.

Location: New England National Park.

Australian distribution: A new record for New South Wales if confirmed. This species has been reported from the Northern Territory.

Staurastrum inconspicuum Nordstedt

Croasdale et al. 1994, p. 102, pl. 91, figs 5–9.

Description: LM: Cells relatively small, quad-radiate, L.cpr 14.2–14.9 µm & L. spr., 12.2–13.6 µm Br.cpr. 10.5–14.1; I. 6.6–6.8 µm. **Figs 35A & B.**

Location: Basket Swamp.

Australian distribution: A new record for New South Wales. Previously recorded from Victoria and the Northern Territory.

Staurastrum cf. ***longebrachiatum*** (Borge) Gutwinski

Thomasson 1972, p. 265, fig 8: 10. as "*Staurastrum longebrachiatum* forma"

Description: LM: Cells bi-radiate, 28.1–30 µm L.spr; 57–60 µm Br.cpr.; I. 5.7–6 µm. Processes terminating to two rather distinct spines. Isthmal region bearing what appears to be rings of granules almost like verrucae. **Fig. 17C.**

Notes: The plants here are identical to what Thomasson (1972) designated as "*S. longebrachiatum* forma" in the broad sense, citing Krieger (1932).

Location: Basket Swamp.

Australian distribution: Possibly a new observation for Australia.

Staurastrum trihedrale Wolle

Croasdale et al. 1994, p. 144, pl. 79, figs 10–13.

Description: LM: Cells triradiate, 45.2–47.4 µm L. × 25.4–27.6 µm Br; I. 10.5 µm. Semicells triangular, cell wall punctate. Sinus closed with the rounded basal angles adjoining with the opposing semi-cell. Apex broadly rounded. In end-view, triangular with rounded angles and concave sides. **Fig. 13E**.

Location: Ebor Common.

Australian distribution: New record for Australia.

Staurastrum cf. ***hardyi*** G.S. West

West 1909, p. 71, pl. 6, figs 21–22.

Description: LM: Cells biradiate, 22.1–25.4 µm L.spr; 40.2–43.6 µm Br.cpr.; I. 4.78–5.3 µm with a ring of granules around the basal inflation. Processes terminating with four spines. SEM: Pores are situated at the base of the apical verrucae as well as scattered throughout the rest of the cell body. **Figs 17D and 36A, B, C, D, E, & F.**

Notes: This form seems to be an intermediate of *Staurastrum hardyi* and *Staurastrum longiradiatum* var. *subnudum* G.S. West; both of which were originally described by West (1909) from samples taken from Yan Yean Reservoir, Victoria. The specimens here share the same size and overall morphology of *S. hardyi* but differ in their semicell body shape. The semicell body observed here is more comparable with *S. longiradiatum* var. *subnudum*, but that species is slightly larger and apparently lacks any apical verrucae.

Location: Basket Swamp.

Staurastrum cf. ***monticulosum*** Brébisson

Vyverman 1991, p. 134, pl. 113, fig. 3.

Description: LM: Cells triradiate, 28.7–29.5 µm L.spr; 22.3–26.7 µm Br. spr.; I. 10–11.9 µm. Cell body smooth, lacking ornamentation. Chloroplast with a single pyrenoid per semicell. **Figs 18C, D, E, F, G & H.**

Notes: Only a few cells of this desmid were encountered and appear most similar to what Vyverman (1991) depicts as *S. monticulosum*. Vyverman (*l.c.*) also states his specimens closely resemble *S. monticulosum* f. *arsenii* Irénée-Marie. Further observations and additional literature reviews are needed to confirm its identity.

Location: Basket Swamp.

Staurodesmus Teiling (1948)

Staurodesmus cf. ***cuspidicurvatus*** Coesel & Meesters

Croasdale et al. 1994, p. 44, pl. 66, figs 19–22.

Basionym: *Staurastrum curvatum* W.West

Heterotypic Synonym: *Staurodesmus cuspidatus* var. *curvatus* (West) Teiling

Description: LM: Cells triradiate, 20.7–23.5 µm L.ssp × 22.3–23.1 µm Br.ssp and 26.4–37.2 µm L.csp × 24.7–25.4 µm Br.csp; I. 5.4–7.2 µm. Sp. 4.1–8.5 µm arising from apex divergently. SEM: Cell wall homogenous with evenly spaced puncta that are especially prominent on the cell apex. **Figs 13G and 35C & D.**

Notes: The plants best match those identified as *Staurastrum curvatum* West in Scott & Prescott (1958) which is now transferred to *Staurodesmus cuspidicurvatus* Coesel & Meesters. The uncertain designation here is due to the many different interpretations and depictions of this species along with morphologically similar entities such as *Staurodesmus patens* var. *inflatus* Coesel & Meesters.

Location: Basket Swamp.

Australian distribution: A new record for New South Wales if confirmed (previously observed from the Northern Territory).

Tetmemorus Ralfs ex Ralfs (1848).

Species from this genus are largely encountered in soft waters, particularly amongst *Sphagnum* vegetation Coesel & Meesters (2007).

Tetmemorus brebissonii Ralfs

Croasdale & Flint 1986, p. 80, pl. 16, figs 10, 11.

Description: LM: Cells cylindrical 132–133 µm in L. × 23.7–28.7 µm Br; I. 20.8–26.6 µm. Cell wall with puncta arranged in vertical rows. SEM: The vertical rows of puncta are ellipsoid scrobiculations with a single fine pore located on the end facing towards the isthmus. **Figs 37A & B.**

Location: Basket Swamp.

Australian distribution: Reported from all States and Territories of Australia except Western Australia and the Australian Capital Territory.

Tetmemorus cf. ***granulatus*** (Brébisson) Ralfs

Croasdale & Flint 1986, p. 81, pl. 17, figs 1, 2.

Description: LM: Cells fusiform and only slightly tapering (no constriction below the apex), 106–127 µm in L. × 23.2–26 µm Br., with an L:B of 4.5–5.3; I. 22.9–24.8 µm. Cell wall puncta arranged irregularly, evenly spaced. **Fig. 13A.**

Notes: Cell dimensions encountered here intermeshed with those of *Tetmemorus laevis* var. *tropica* Krieger; certain distinction between the two relies on observations of the differently shaped zygospores see Croasdale and Flint (1986).

Location: Basket Swamp and Ebor Common.

Australian distribution: Previously reported from Queensland, New South Wales, Tasmania and Western Australia.

Tetmemorus laevis Ralfs

Croasdale and Flint 1986, p. 81, pl. 17, figs 3–6.

Description: LM: Cells fusiform only slightly tapering, 75–121 µm in L. × 20.5–30.3 µm Br., with an L:B of 3.5–4; I. 19.5–29.2 µm. Cell wall puncta arranged irregularly, evenly spaced. **Fig. 13B.**

Location: Ebor Common.

Australian distribution: Recorded from most Australian States and Territories except for Western Australia, Australian Capital Territory and Victoria.

Triploceras Bailey (1851).

Triploceras gracile Bailey

Croasdale and Flint 1986, p. 77, pl. 15, figs 1–3, 8.

Description: LM: Cell 195 µm L.csp. × 16.8 µm Br.csp.; I. 9.2 µm Cells ornamented with whorls of simple, single spines. **Figs 37C & D.**

Notes: Putatively a highly polymorphic taxon; probably in part due to the type description and illustration being of such poor quality (see (West 1909)) that distinction from other varieties are possibly synonymous or potentially concealing diversity. Ling and Tyler (2000) discuss this issue in greater detail. Of the few cells observed here, they best belong to the type variety.

Location: Basket Swamp.

Australian distribution: Various varieties and unnamed forms of *T. gracile* have been documented across eastern Australia – Northern Territory, Queensland, New South Wales, Victoria and Tasmania.

Xanthidium Ehrenberg ex Ralfs (1848).

Xanthidium armatum var. ***basidentatum*** Nordstedt

Croasdale & Flint 1988, p. 120, pl. 57 fig. 3.

Description: LM: Cell 85 µm L. × 68.8 µm Br. Central ornament granules arranged in a ring. **Fig. 13D.**

Notes: This is probably a distinct species rather than a mere variety since no intermediate forms of the type variety have been observed so far. It should not be confused by morphology or name with the species *Xanthidium basidentatum* (Børgesen) Coesel.

Location: Basket Swamp.

Australian distribution: Playfair (1917) cites this variety from New South Wales but no voucher were reported. Originally described from New Zealand (Nordstedt 1887).

Xanthidium octocorne Ralfs

Coesel & Meesters 2007, p. 155, pl. 85 figs 9–11.

Description: LM: Cell relatively small, each angle furnished with a simple spine. **Fig. 13C.**

Notes: The single cell observed here could be assigned to the variety *depressum* (Grönblad) Coesel which is broader than long in cell dimensions than *X. octocorne* var. *octocorne*.

Location: Basket Swamp.

Australian distribution: Previously reported from the Northern Territory, Queensland, New South Wales and Victoria.

Xanthidium cf. ***octonarium*** Nordstedt

Nordstedt 1888, p. 42, pl. 4 fig. 22.

Croasdale & Flint 1988, p. 123, pl. 58 figs 1&2.

Description: LM: Cells 111–118 µm L.ssp × 74–80 µm Br.ssp., I. 23.2–26.4 µm with Th. of 57 µm; semicells depressed-circular with a truncated apex and rounded basal angles, margins possess nine or up to ten upwardly curving spines (5–16 µm long) arranged in pairs on either side. Central area of semicell noticeably thickened in end-view, in face-view this region has pores(?) visibly connected in a reticulate manner, cell wall punctate elsewhere. **Fig. 13H.**

Notes: Nordstedt's *l.c.* original concept was based on only a few semicells, with most having four spines on either side (totalling eight, hence the species epithet). However, he mentions one specimen having five spines on one side which seems to be an intermediate connection to the predominately five-spined (ten per semicell) forms observed in this survey. All other Australian records that describe and/or depict this entity mention the number spines being four.

Location: Basket Swamp.

Australian distribution: A new record for New South Wales if confirmed. However, *Xanthidium octonarium* var. *coronatum*, which has in total only six spines per semicell, as described by Playfair (1908) has been reported from this State.

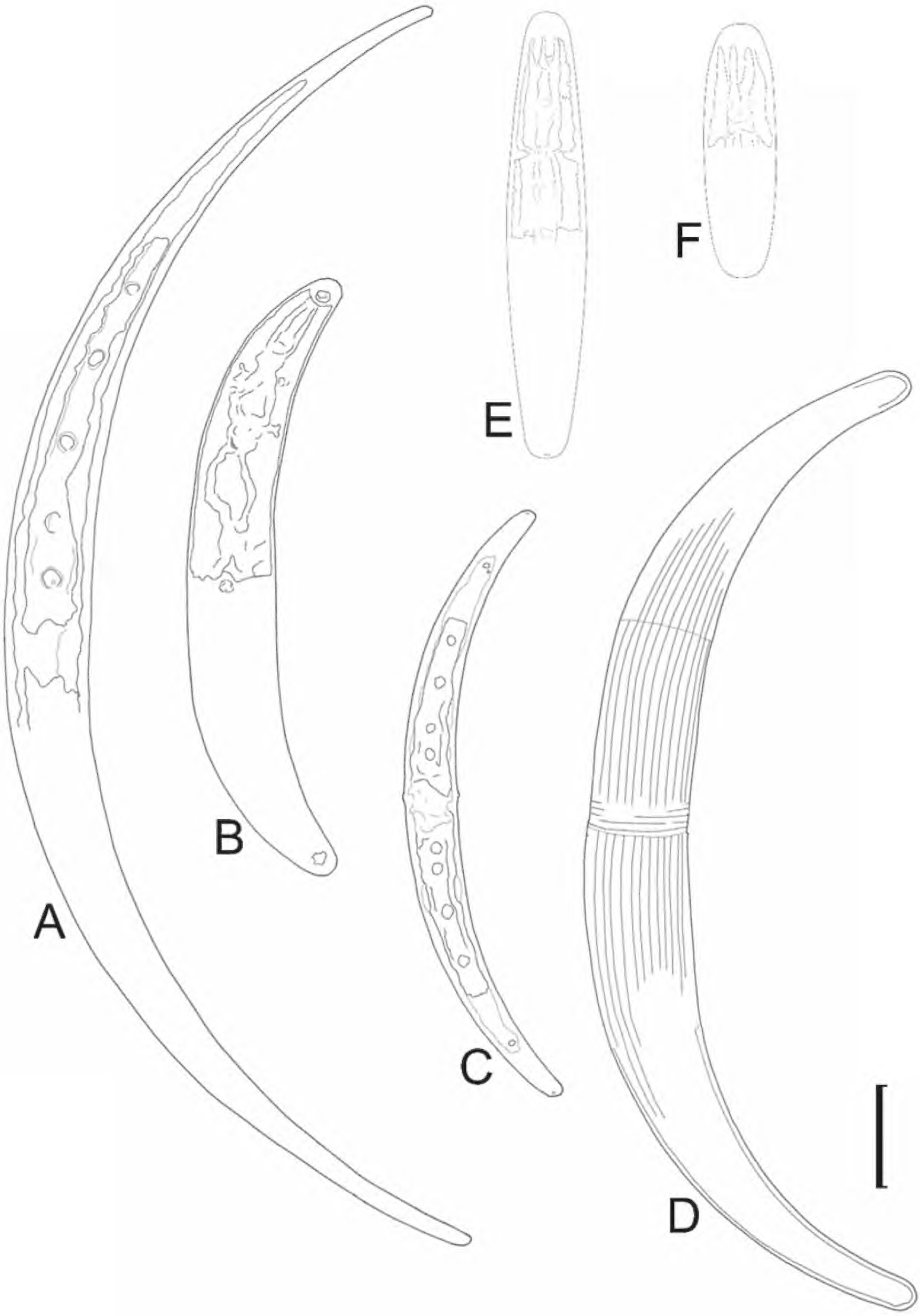

Fig. 8. Drawings of desmids based on light microscope images, **A.** *Closterium dianae* var. *arcuatum*, **B.** *C. abruptum* var. *brevius*, **C.** *C.* cf. *calosporum*, **D.** *C. Cynthia*, **E.** *C. closterioides* var. *intermedium* & **F.** *C. navicula*. Scale bar = 20 µm.

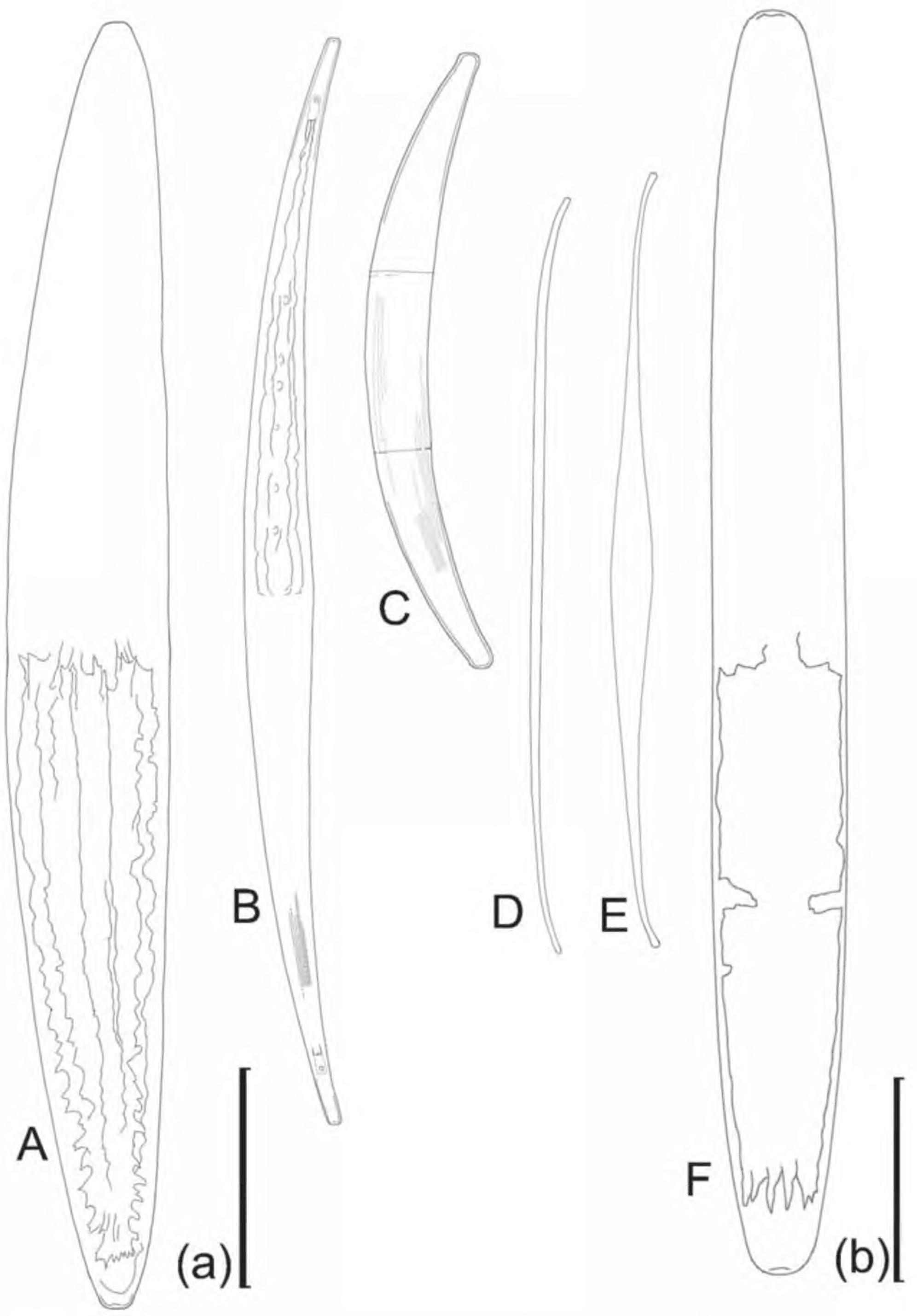

Fig. 9. Drawings of desmids based on light microscope images, **A.** *Closterium lunula*, **B.** *C. ralfsii* var. *hybridum*, **C.** *C. striolatum*, **D.** *C. gracile*, **E.** *C. kuetzingii* var. *procerum* & **F.** *C. closterioides.* Scale bar: (a) = 100 μm for A, B & C; (b) = 50 μm for D, E & F.

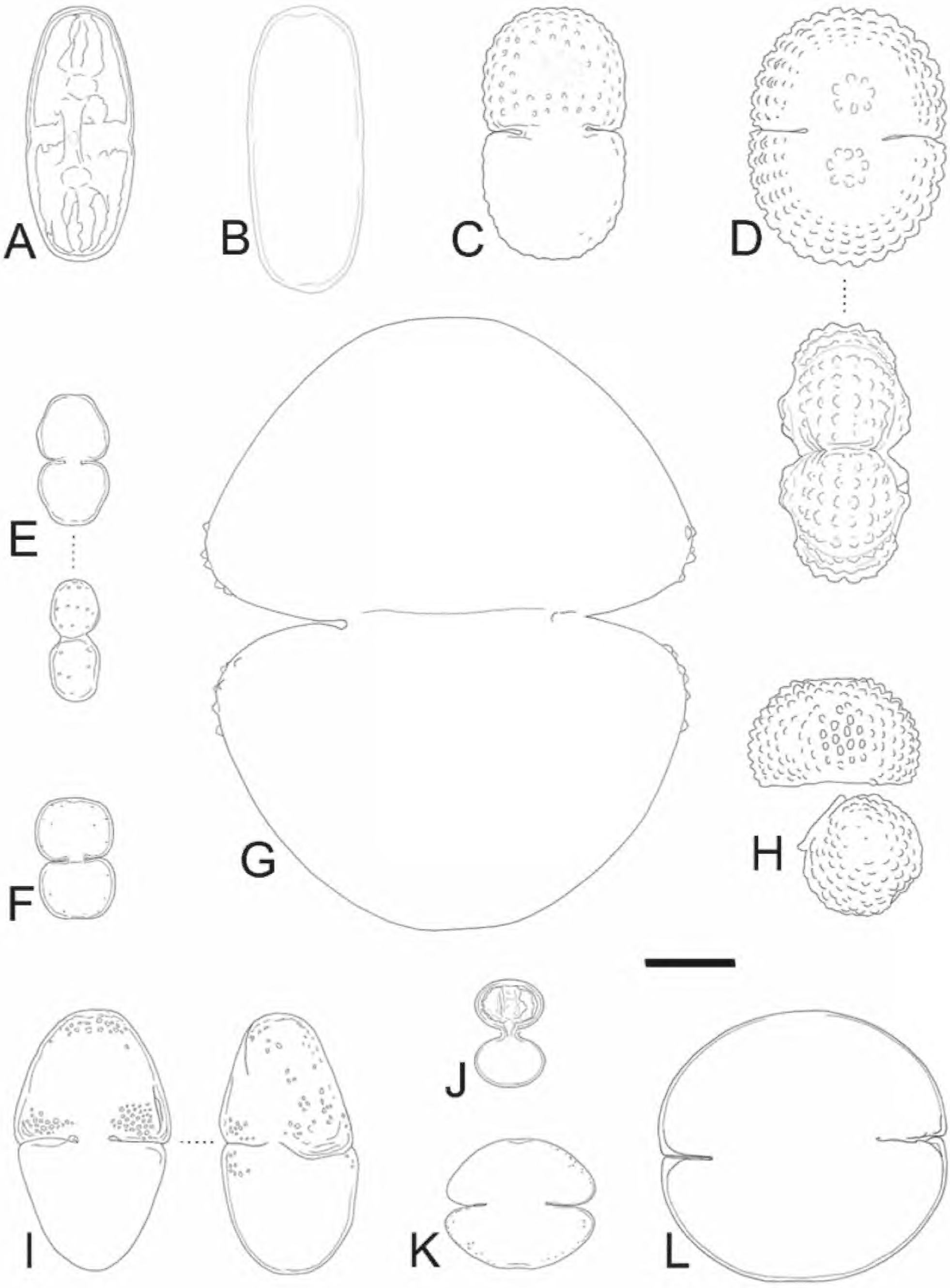

Fig. 10. Drawings of desmids based on light microscope images, **A.** *Actinotaenium cucurbitinum*, **B.** *A. diplosporum* var. *americanum*, **C.** *Cosmarium amoenum* var. *mediolaeve*, **D.** *C. quadrifarium* var. *simplex*, **E.** *C.* cf. *zonatum* var. *compressum*, **F.** *C.* cf. *difficillimum*, **G.** *C. askenasyi*, **H.** *C. margaritiferum* f. *regularius*, **I.** *C. spirale*, two specimens, **J.** *C. contractum*, **K.** *C. dorsitruncatum* & **L.** *C. obsoletum* var. *sitvense*. Scale bar = 20 μm.

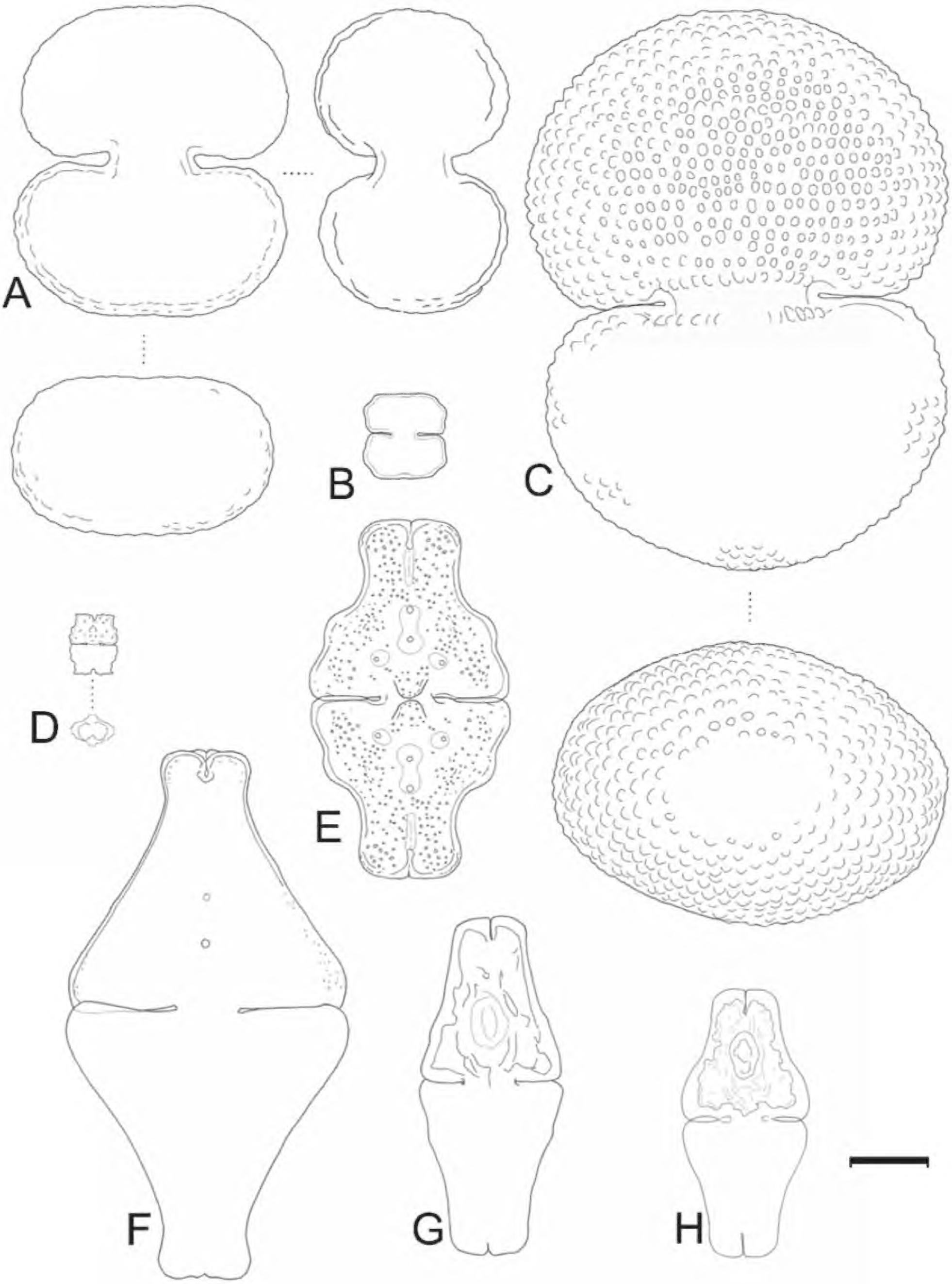

Fig. 11. Drawings of desmids based on light microscope images, **A.** *Cosmarium* cf. *reniforme* var. *compressum*, **B.** *C. regnellii*, **C.** *C. amplum*, **D.** *Euastrum denticulatum* var. *quadrifarium,* **E.** *E. sinuosum* var. *germanicum*, **F.** *E. didelta* var. *bengalicum*, **G.** *E. ansatum* & **H.** *E. ansatum* var. *simplex.* Scale bar = 20 μm.

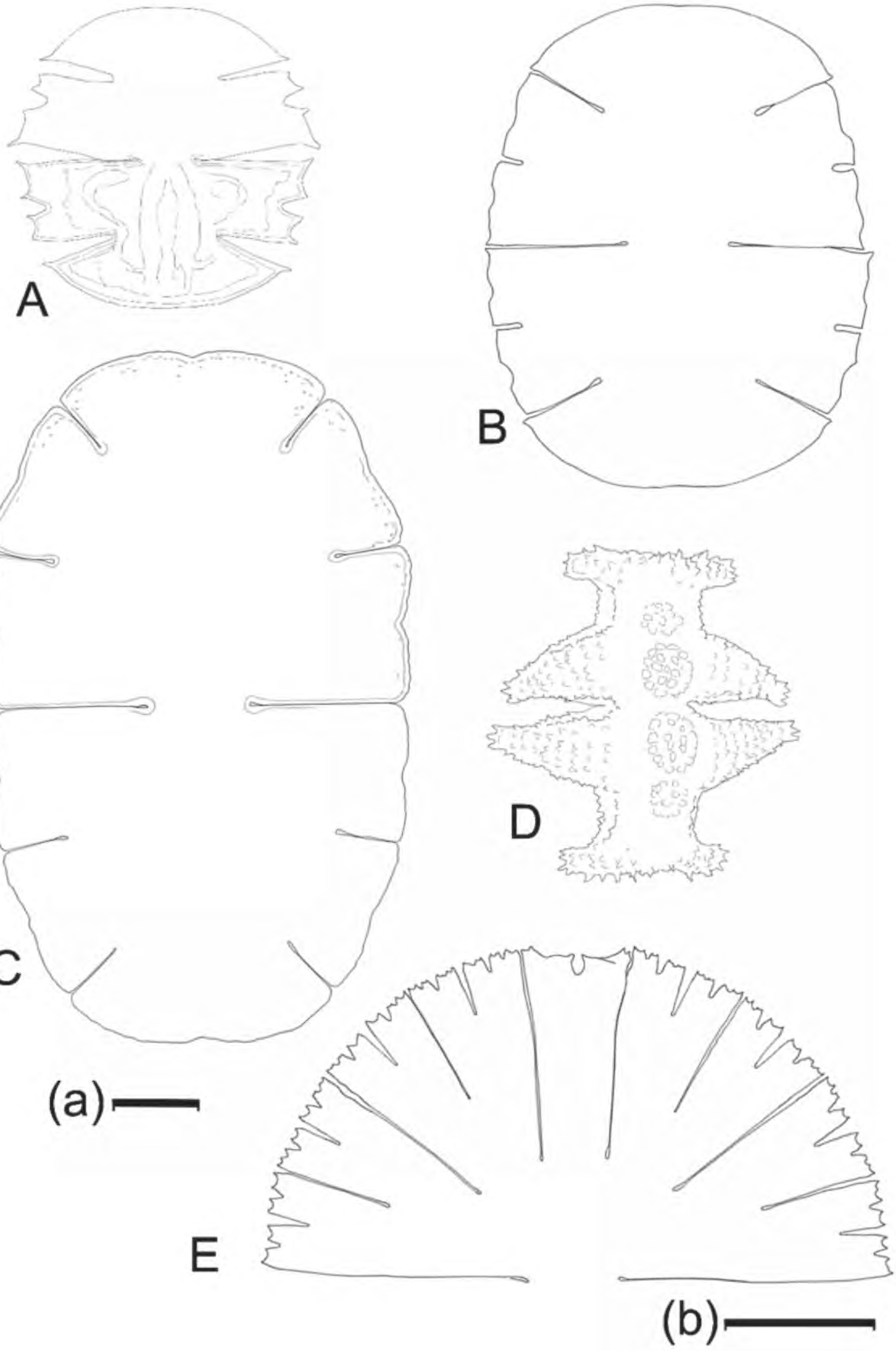

Fig. 12. Drawings of desmids based on light microscope images, **A.** *Micrasterias decemdentata,* **B.** *M. truncata* var. *crenata* **C.** *M. jenneri,* **D.** *M. bicoronata* & **E.** *M. thomasiana* var. *notata.* Scale bar: (a) = 20 μm, for A, B & C; (b) = 50 μm for D & E.

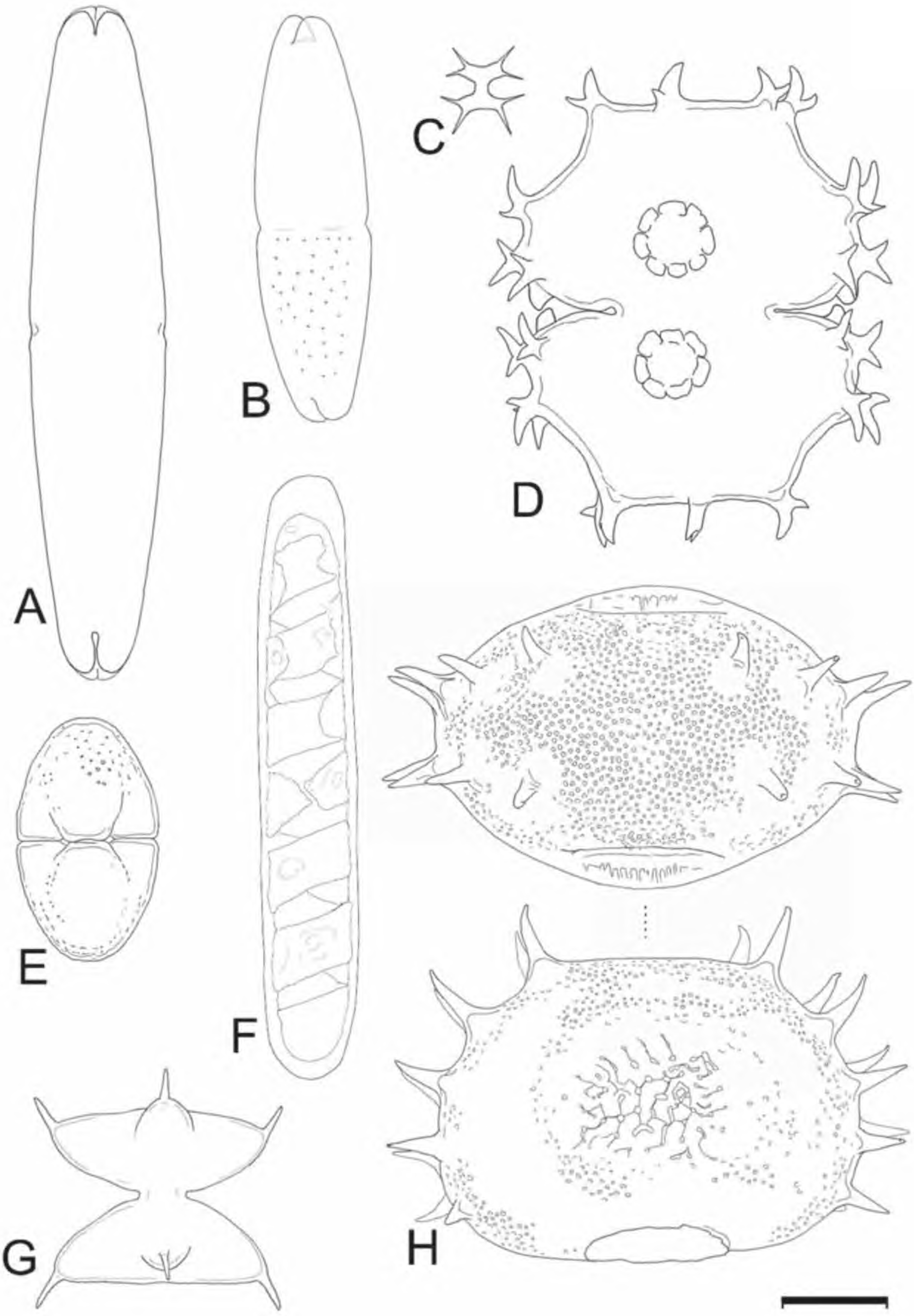

Fig. 13. Drawings of desmids based on light microscope images, **A.** *Tetmemorus* cf. *granulatus*, **B.** *T. laevis*, **C.** *Xanthidium octocorne*, **D.** *X. armatum* var. *basidentatum*, **E.** *Staurastrum trihedrale*, **F.** *Spirotaenia condensata*, **G.** *Staurodesmus* cf. *cuspidicurvatus*, **H.** *X.* cf. *octonarium*. Scale bar = 20 μm.

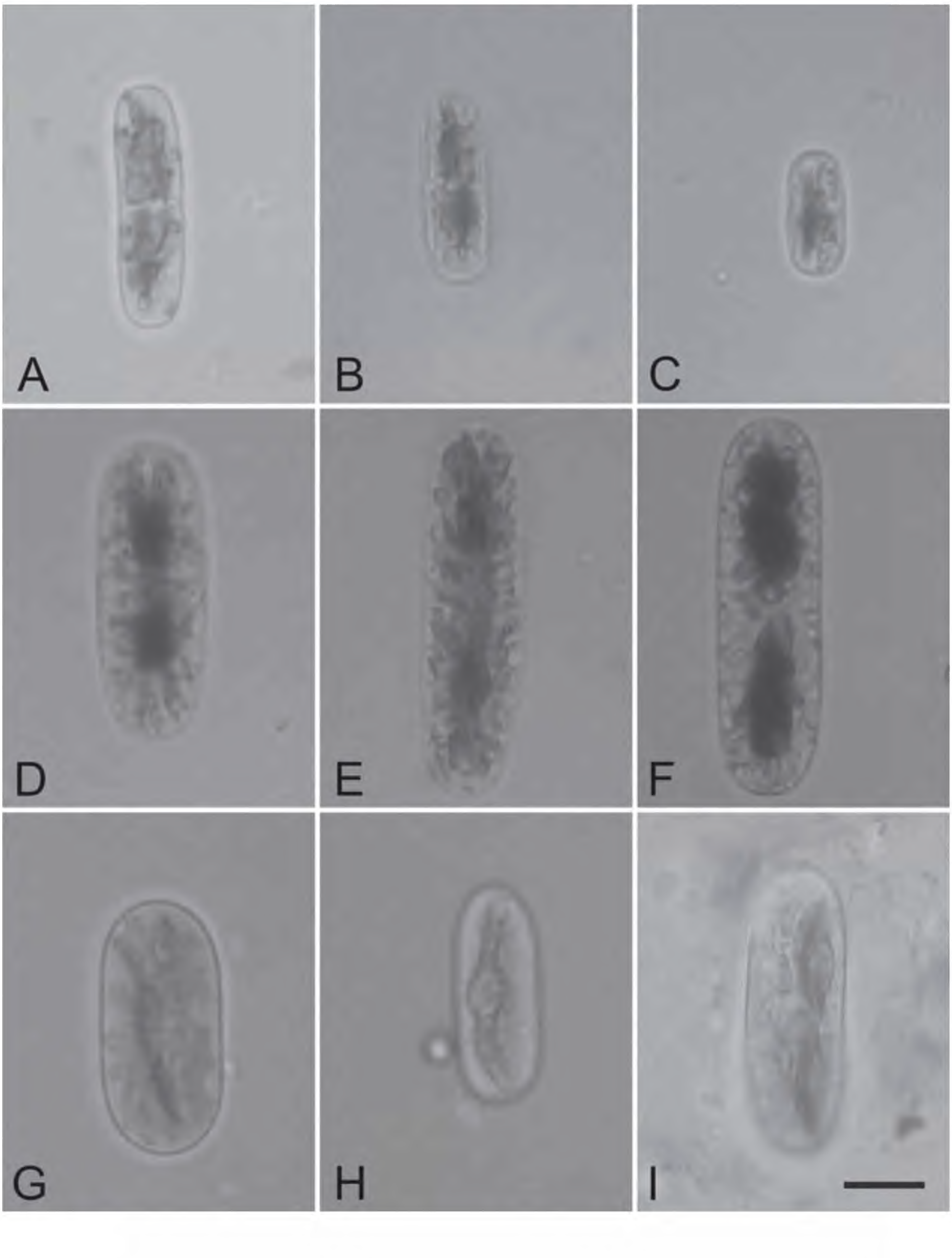

Fig. 14. Light micrographs of desmids, **A**, **B** & **C.** *Cylindrocystis cushleckae*, **D**, **E**, & **F.** *C. brebissonii var. minor*, **G.** *C. gracilis*, **H.** *Mesotaenium macrococcum*, & **I.** *M. endlicherianum*. Scale bar = 10 μm.

Fig. 15. Light micrographs of desmids, **A.** *Cylindrocystis crassa*, **B** & **C.** *C.* cf. *brebissonii* var. *turgida*, **D.** *Netrium digitus*, **E.** *Tortitaenia obscura* & **F.** *Penium exiguum*. Scale bar = 20 μm.

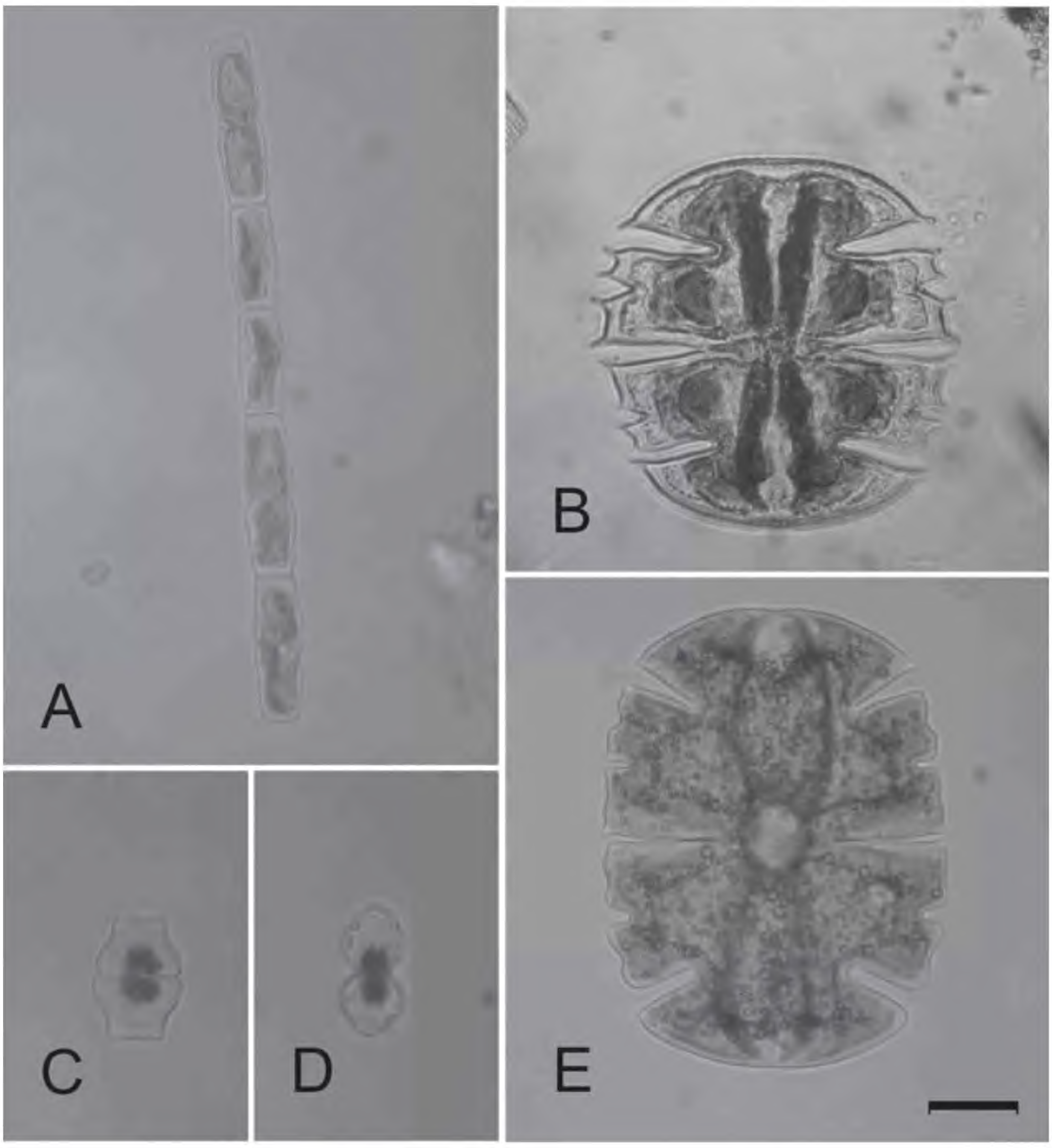

Fig. 16. Light micrographs of desmids, **A.** *Groenbladia bourrellyi,* **B.** *Micrasterias decemdentata*, **C.** *Euastrum cf. luetkemuelleri var. laterepunctatum,* **D.** *Euastrum* cf. *luetkemuelleri* var. *laterepunctatum* (sideview) & **E.** *M. truncata var. crenata* Scale bar = 20 μm.

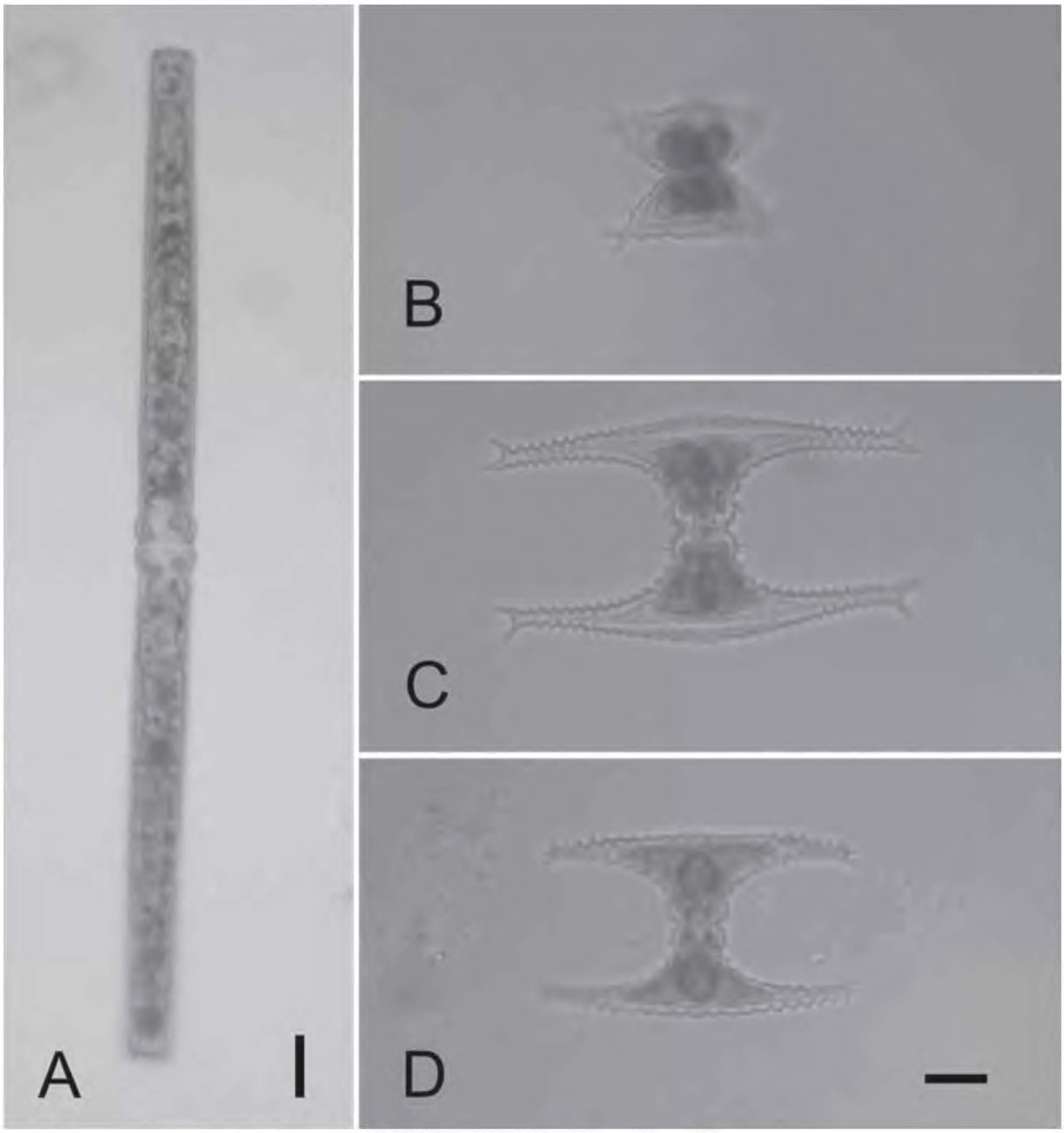

Fig. 17. Light micrographs of desmids, **A.** *Pleurotaenium tridentulum,* **B.** *Staurastrum* cf. *avicula*, **C.** *S.* cf. *longebrachiatum* & **D.** *Staurastrum* cf. *hardyi*. Scale bar A = 20 μm for A; D = 10 μm for B, C & D.

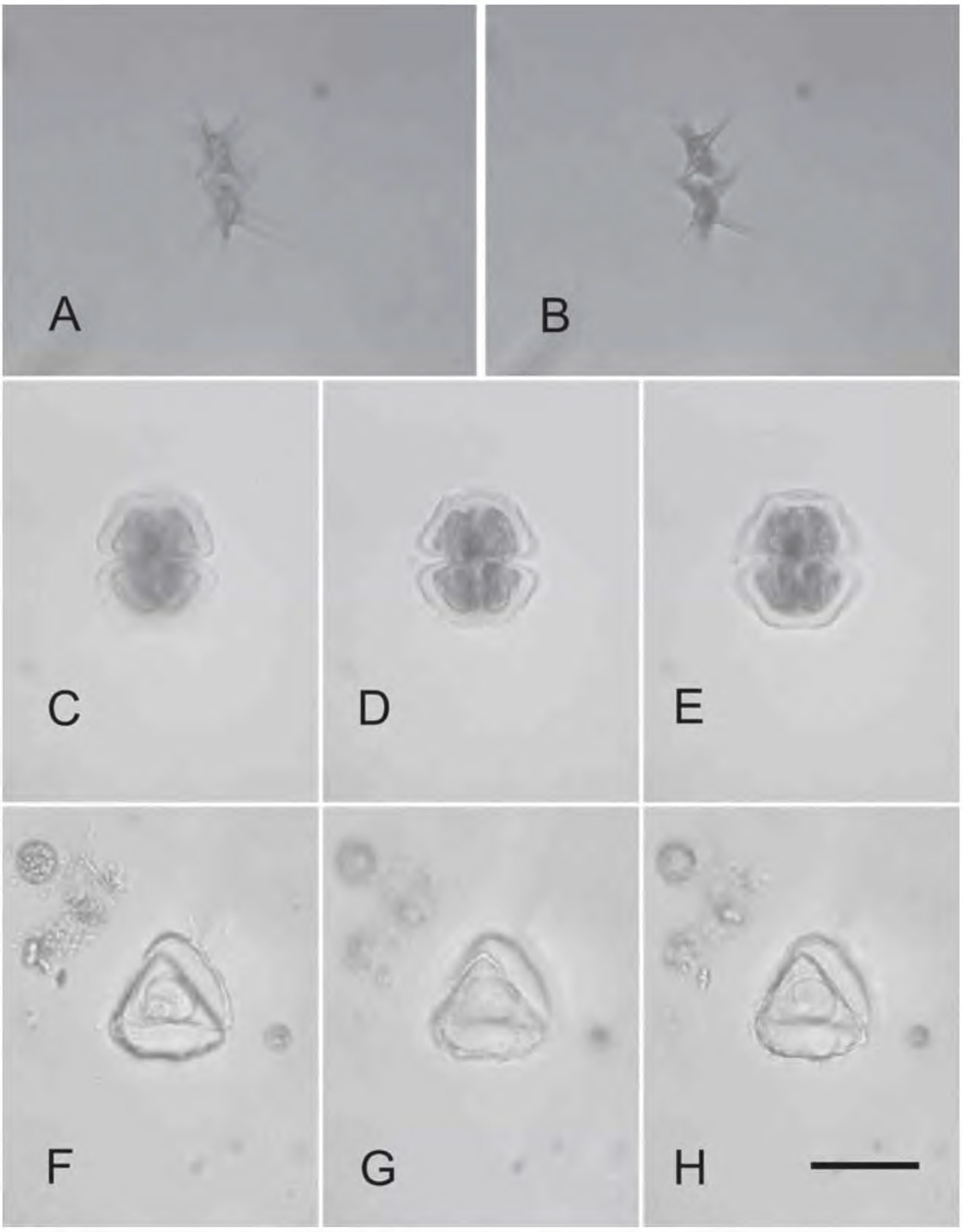

Fig. 18. Light micrographs of desmids, **A** *&* **B.** *Staurastrum aureolatum* (different focal planes), **C**, **D** & **E.** *Staurastrum* cf. *monticulosum* (different focal planes) & **F**, **G** & **H.** *Staurastrum* cf. *monticulosum* (apical view; different focal planes). Scale bar = 20 μm.

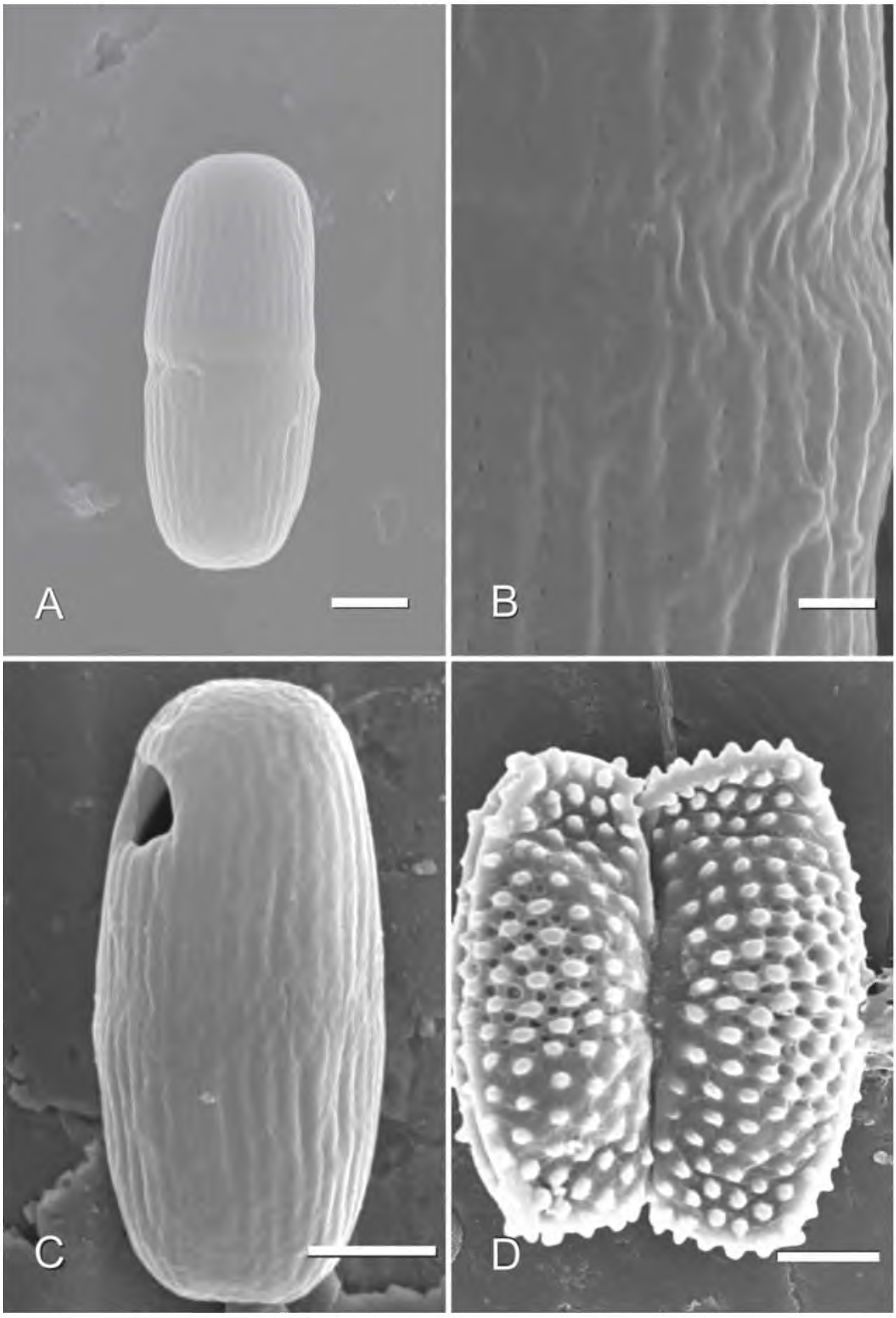

Fig. 19. Scanning electron micrographs of desmids, **A.**, **B.** & **C.** *Actinotaenium* cf. *phymatosporum*. **D.** *Cosmarium* cf. *neapolitanum* var. *australicum*. Scale bar A & C = 5 µm; B = 1 µm; D = 10 µm.

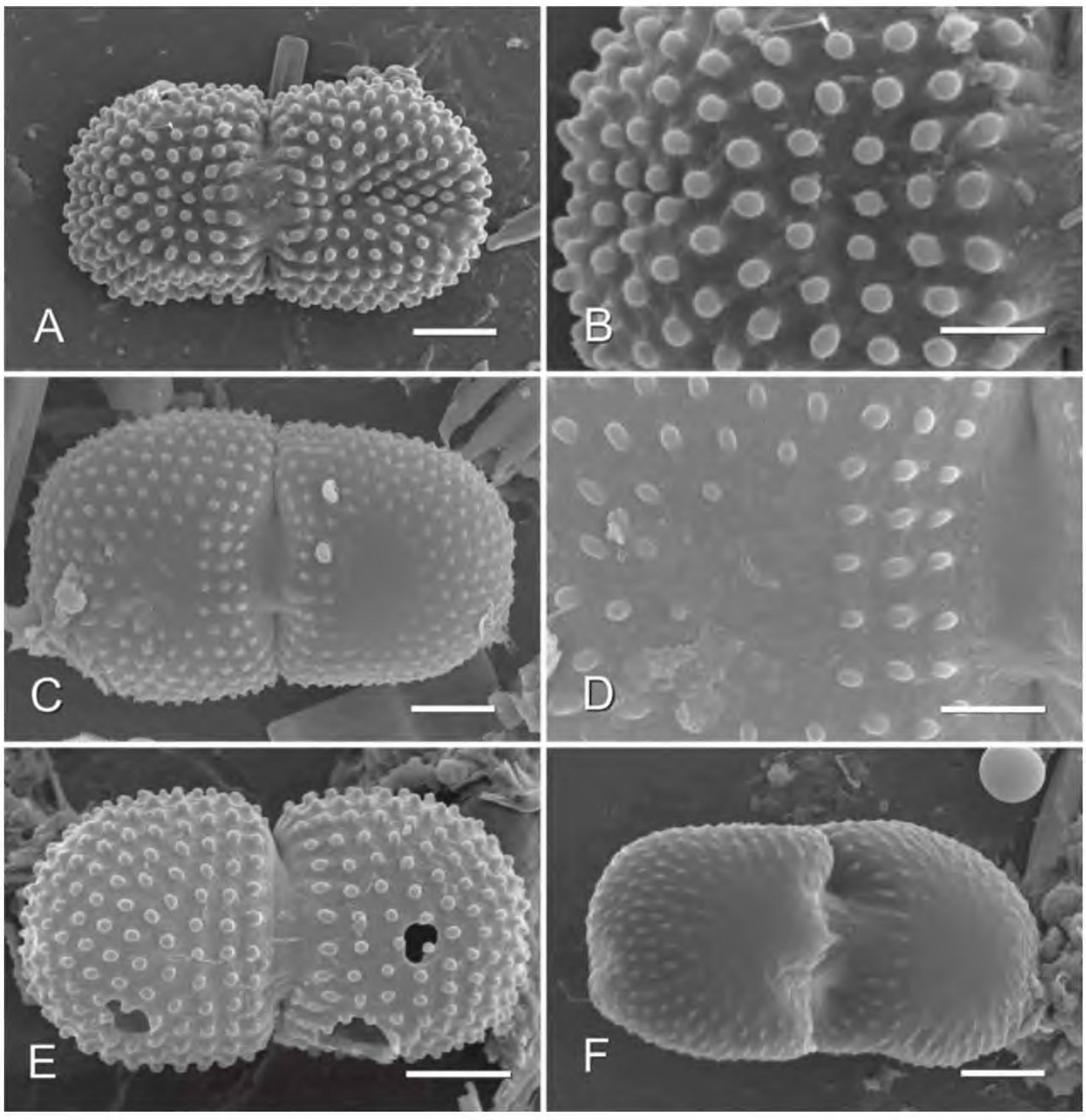

Fig. 20. Scanning electron micrographs of desmids, **A.**, **B.** & **E.** *Cosmarium amoenum*. **C.**, **D.** & **F.** *Cosmarium amoenum* var. *mediolaeve*. Scale bar A, C, E & F = 10 μm; B & D = 5 μm.

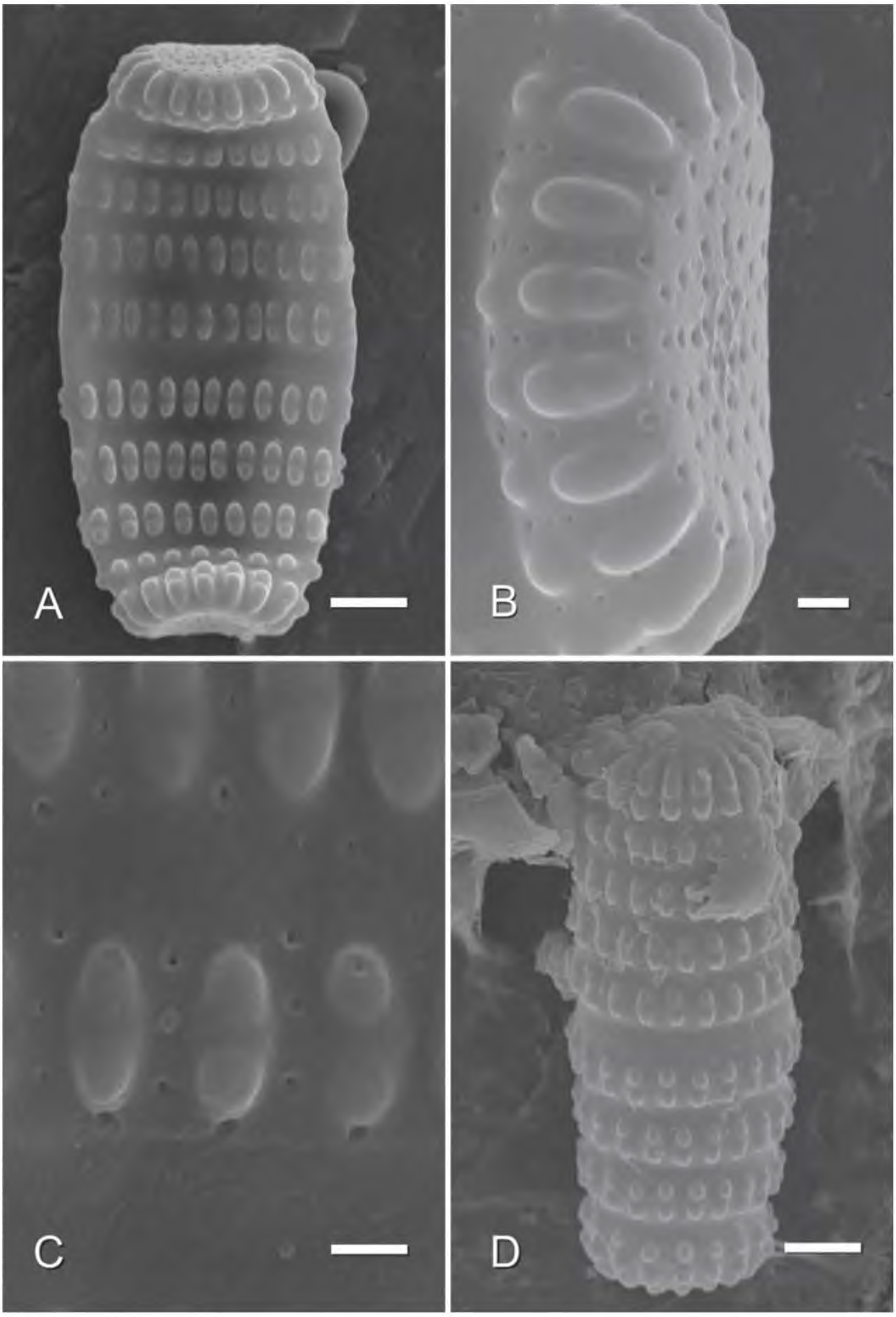

Fig. 21. Scanning electron micrographs of desmids, **A.** – **D.** *Cosmarium annulatum*. Scale bar A & D = 5 µm; B & C = 1 µm.

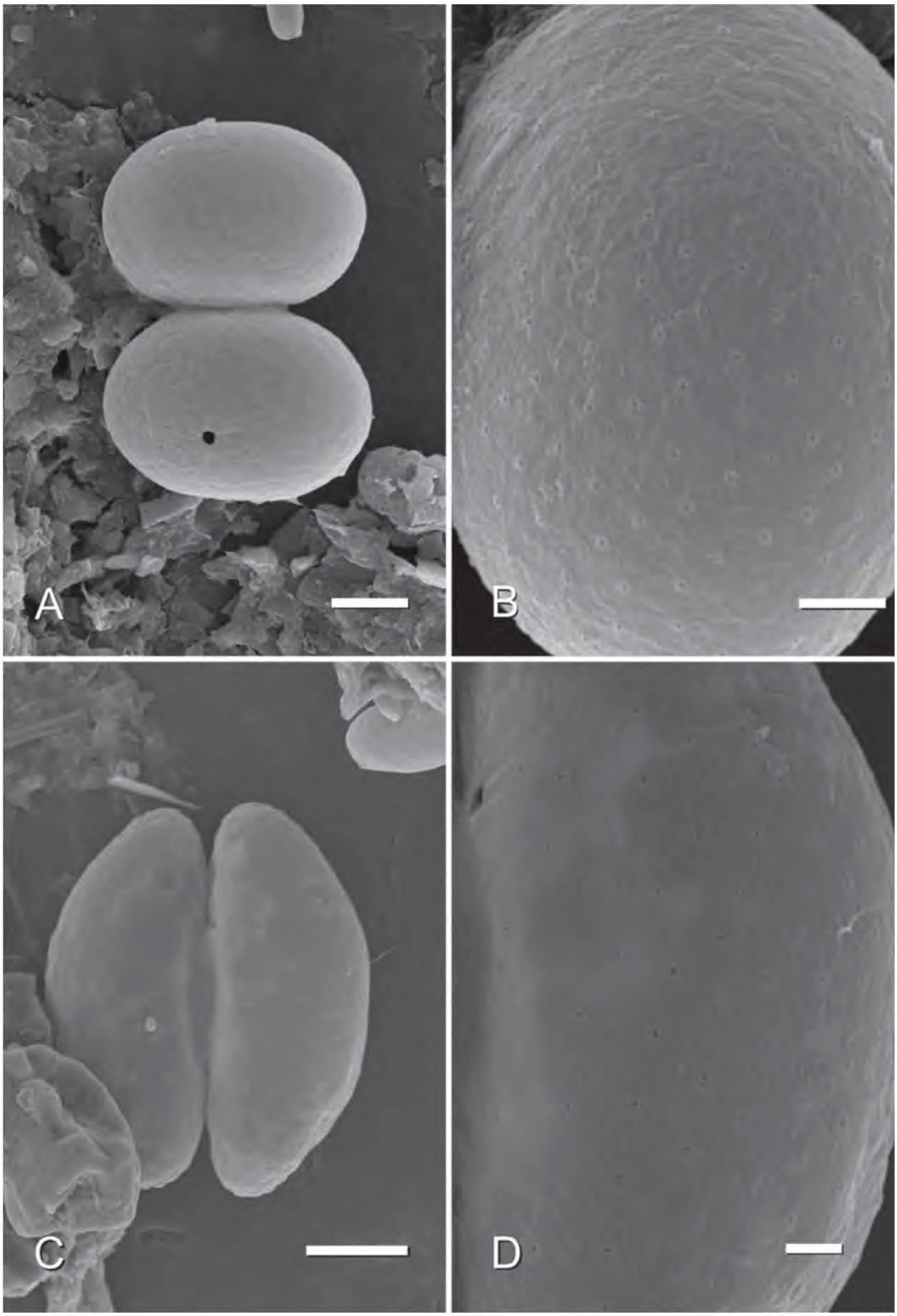

Fig. 22. Scanning electron micrographs of desmids, **A.** & **B.** *Cosmarium contractum*. **C.** & **D.** *C. dorsitruncatum*. Scale bar A = 5 µm; B & D = 2 µm; C = 10 µm.

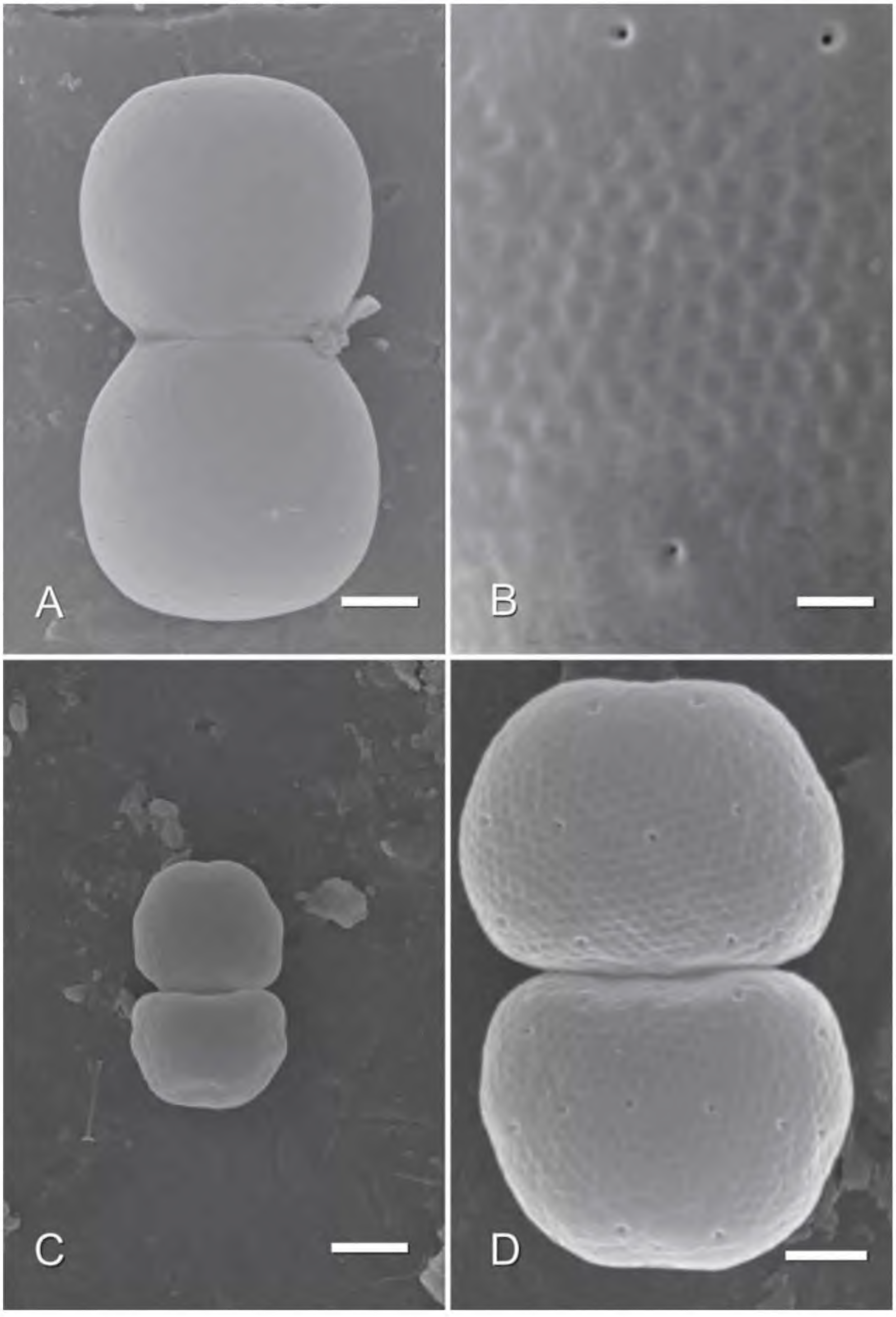

Fig. 23. Scanning electron micrographs of desmids, **A.** & **B.** *Cosmarium* cf. *difficillimum*. **C.** & **D.** *C.* cf. *difficile* var. *messikommeri*. Scale bar A & D = 5 µm; B = 1 µm; C = 2 µm.

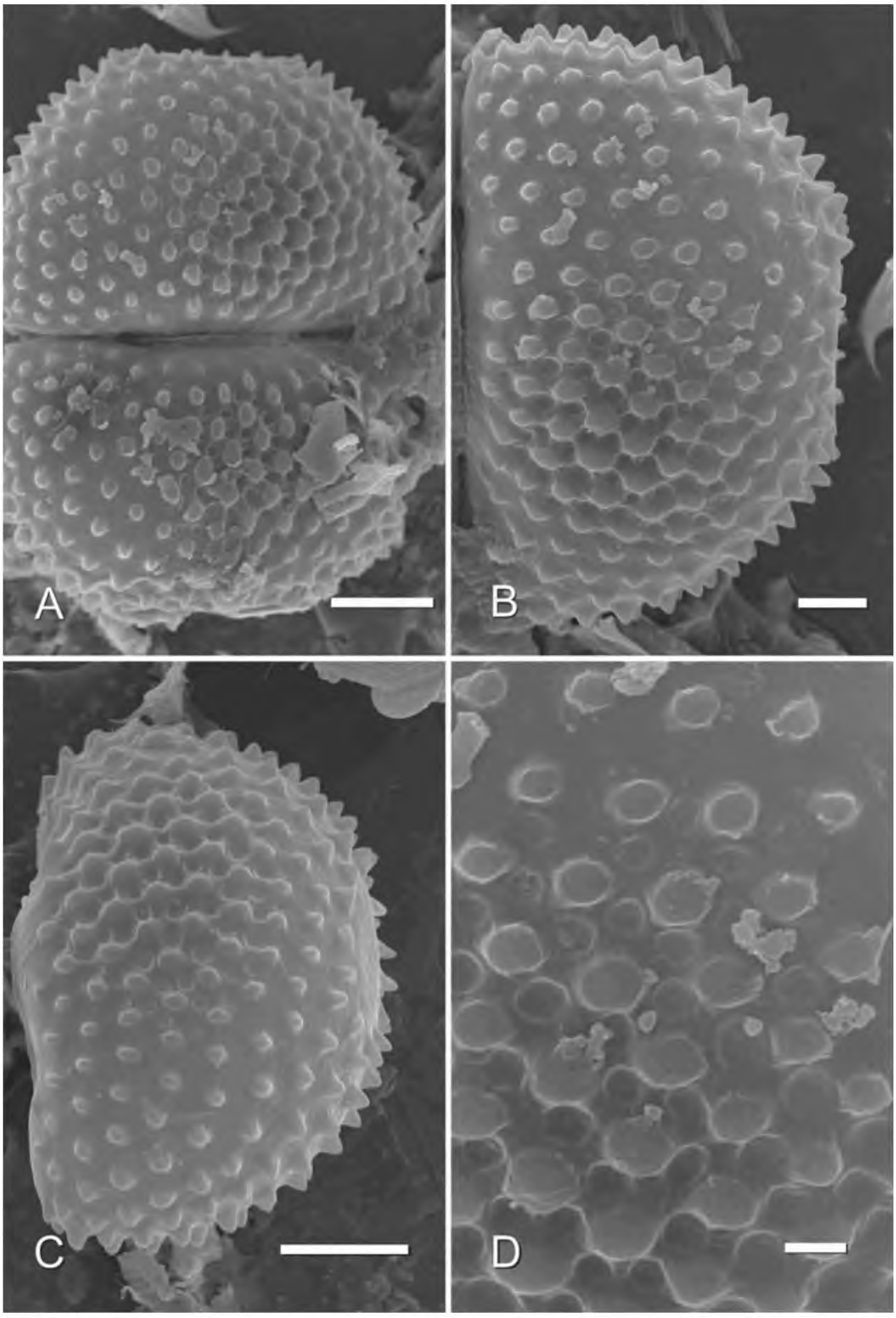

Fig. 24. Scanning electron micrographs of desmids, **A.** – **D.** *Cosmarium margaritiferum* f. *regularius.* Scale bar A & C = 10 µm; B = 5 µm; D = 2 µm.

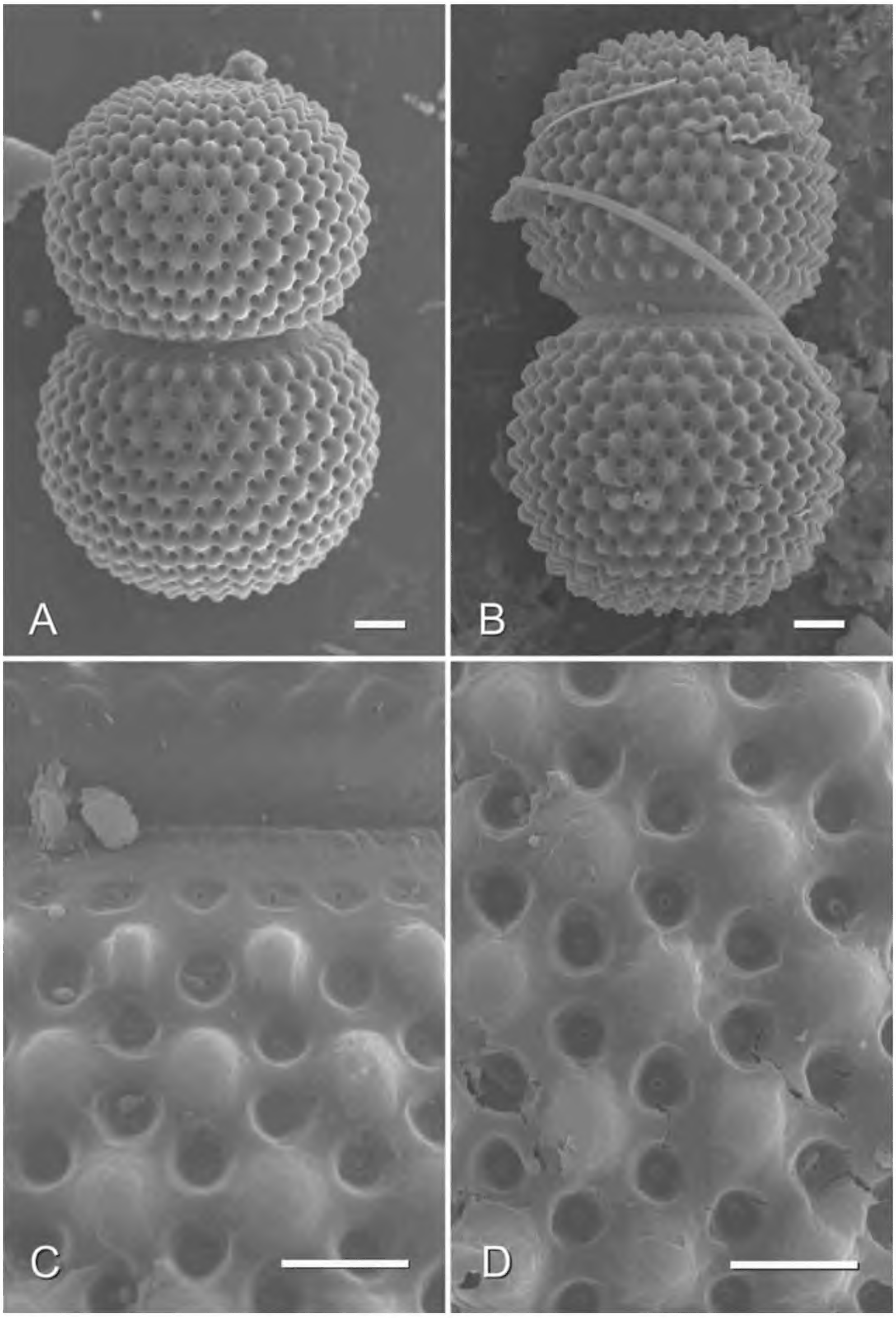

Fig. 25. Scanning electron micrographs of desmids, **A.** – **D.** *Cosmarium striolatum* var. *nordstedtii.* Scale bar A & B = 10 μm; C & D = 5 μm.

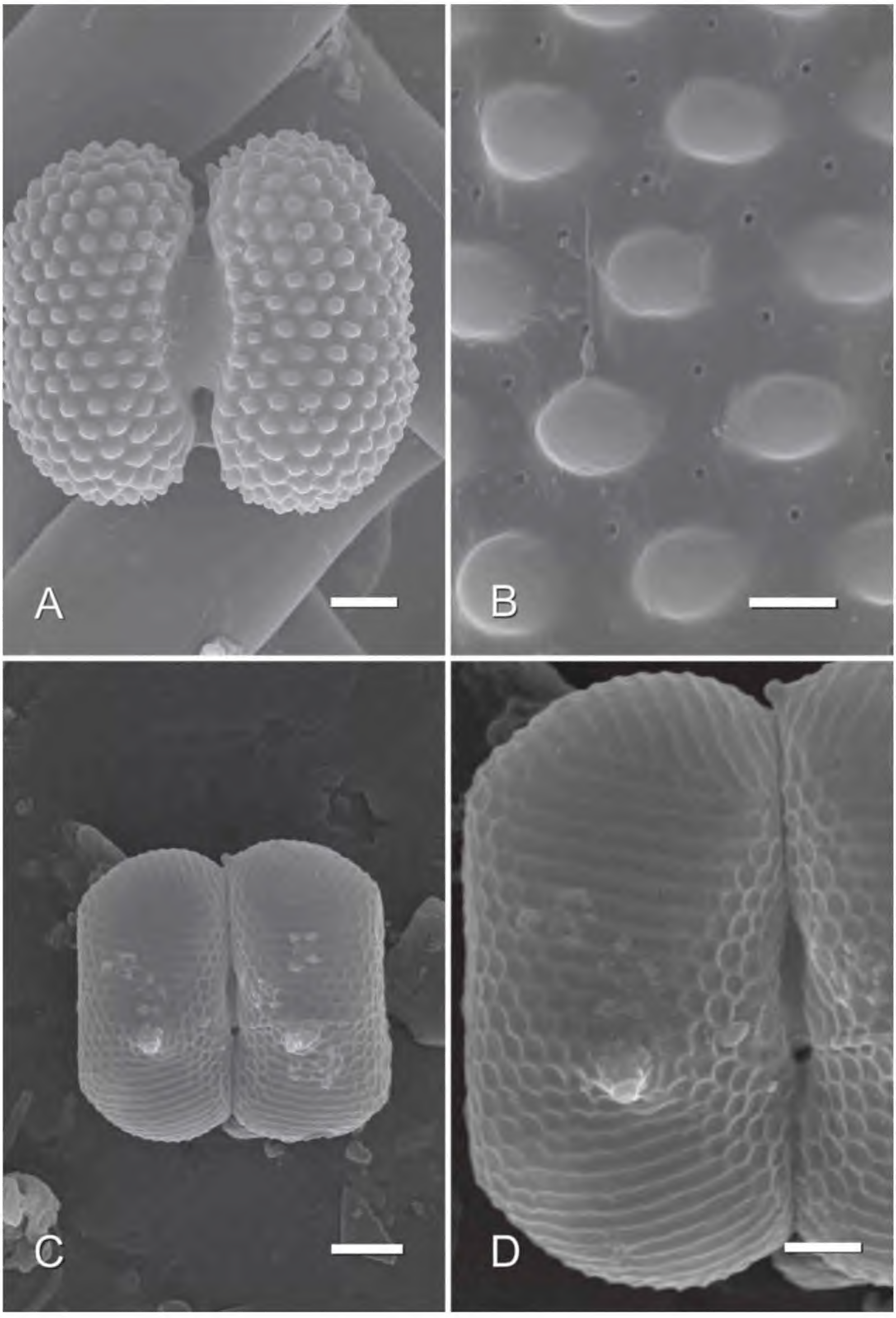

Fig. 26. Scanning electron micrographs of desmids, **A.** & **B.** *Cosmarium* cf. *reniforme var. compressum*. **C.** & **D.** *C. subadoxum*. Scale bar A = 10 µm; B & C = 2 µm; D = 1 µm.

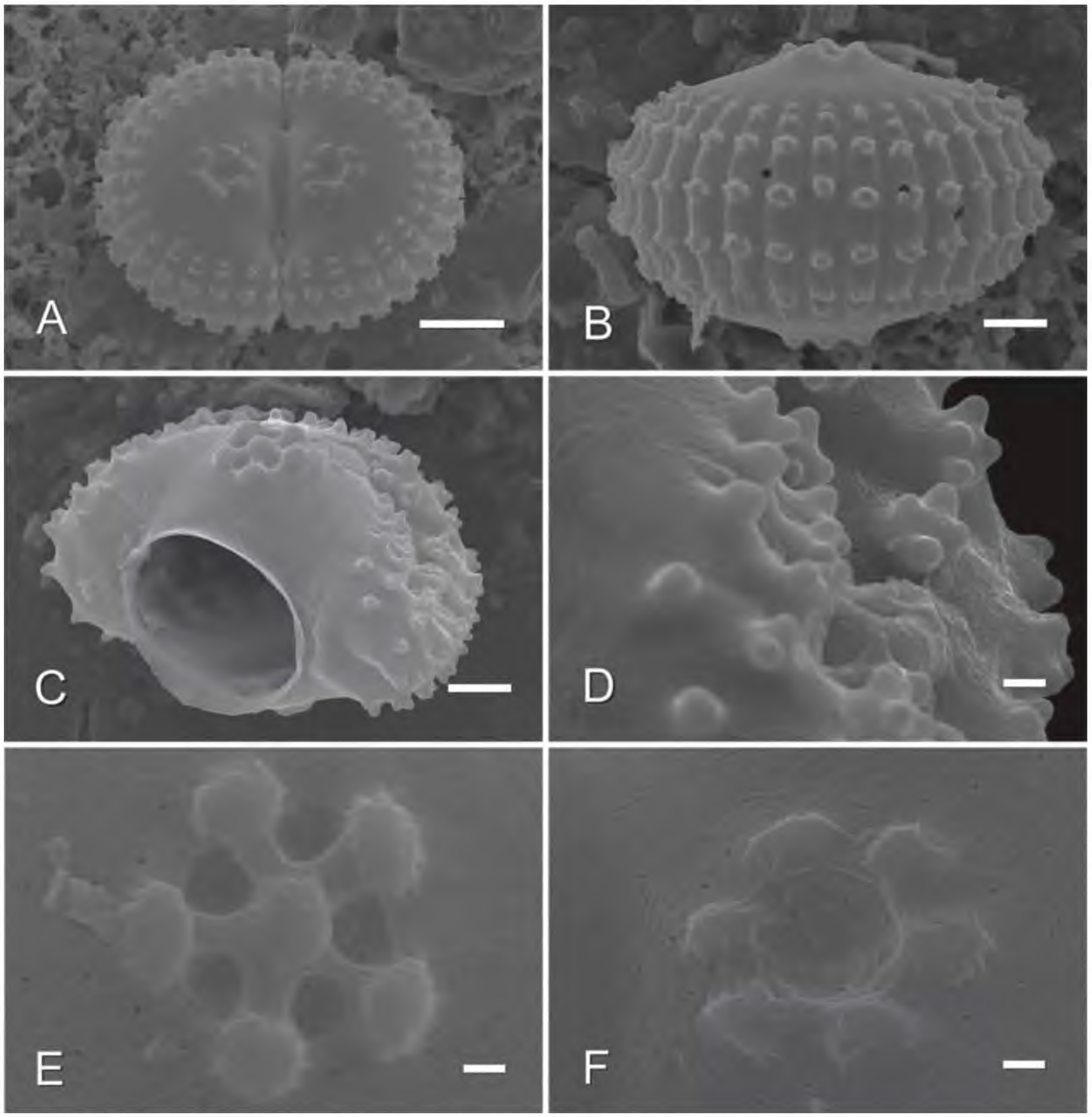

Fig. 27: Scanning electron micrographs of desmids, **A.** – **F.** *Cosmarium quadrifarium* var. *simplex.* Scale bar A = 10 µm; B & C = 5 µm; D, E & F = 1 µm.

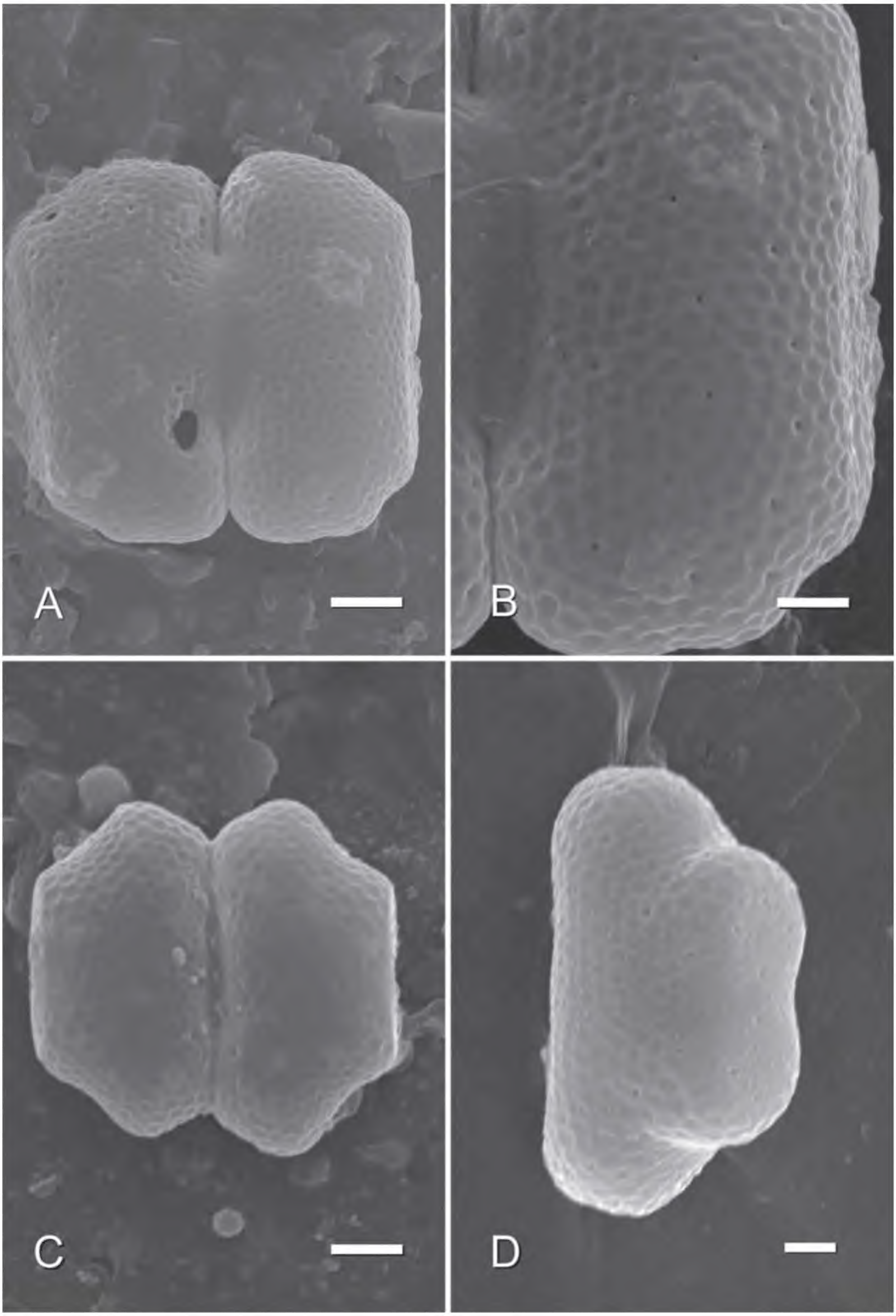

Fig. 28. Scanning electron micrographs of desmids, **A.** – **D.** *Cosmarium regnellii.* Scale bar A & C = 2 µm; B & D = 1 µm.

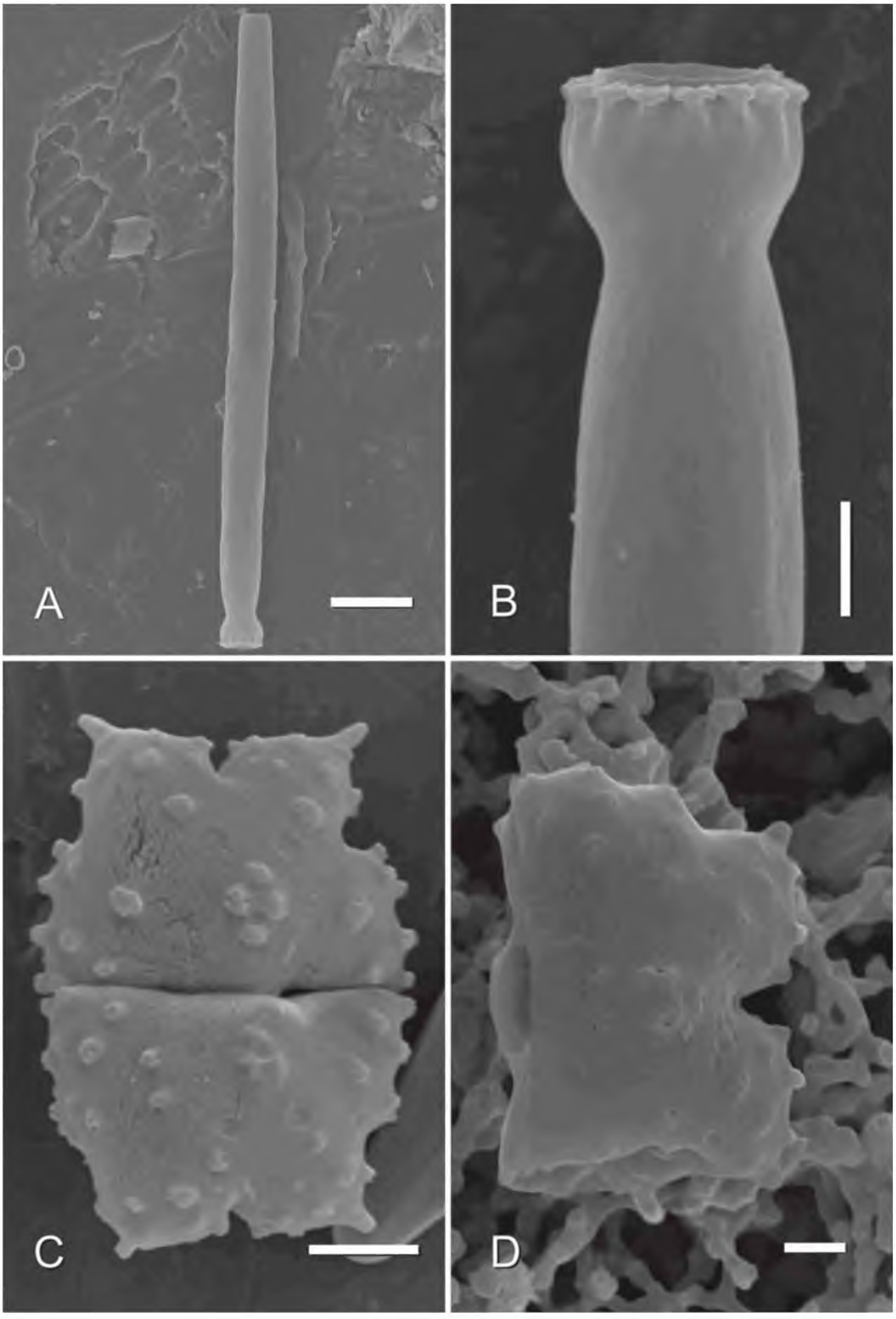

Fig. 29. Scanning electron micrographs of desmids, **A.** & **B.** *Docidium baculum*. **C.** & **D.** *Euastrum denticulatum* var. *quadrifarium*. Scale bar A = 20 µm; B & C = 5 µm; D = 2 µm.

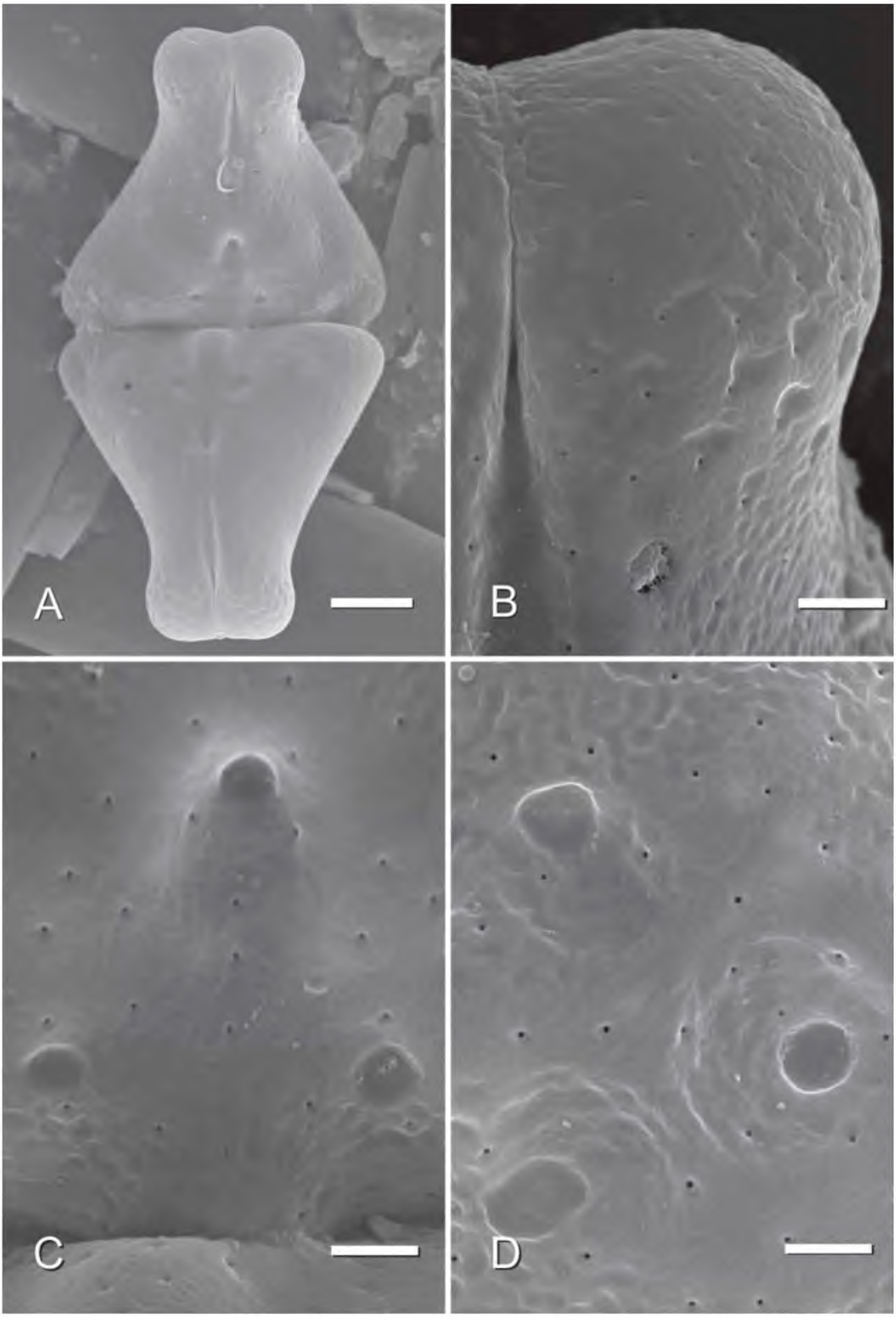

Fig. 30. Scanning electron micrographs of desmids, **A.** – **D.** *Euastrum* cf. *ansatum* var. *triporum*. Scale bar A = 10 μm; B, C & D = 2 μm.

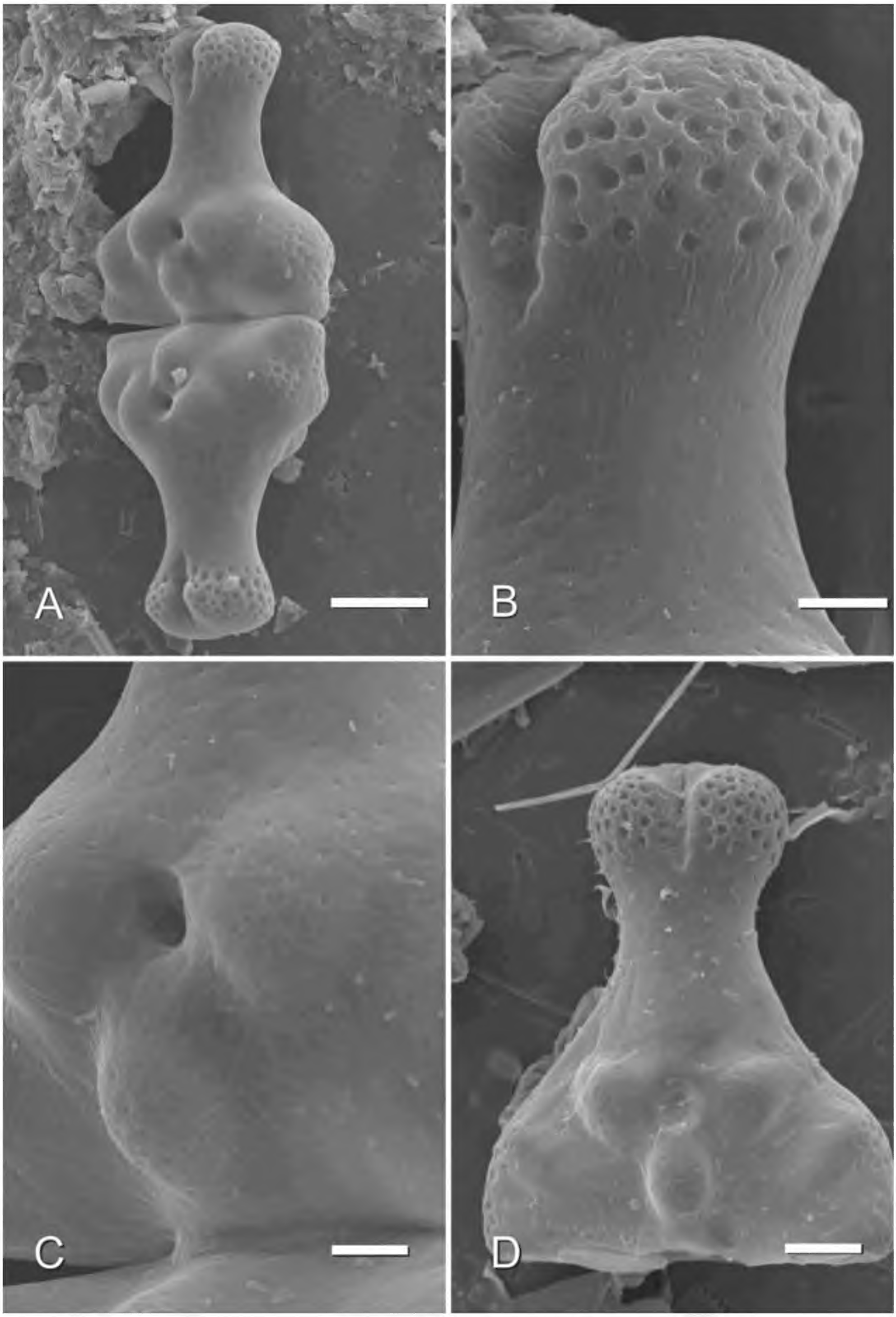

Fig. 31. Scanning electron micrographs of desmids, **A. – D.** *Euastrum longicolle* var. *australicum*. Scale bar A = 20 μm; B & C = 5 μm; D = 10 μm.

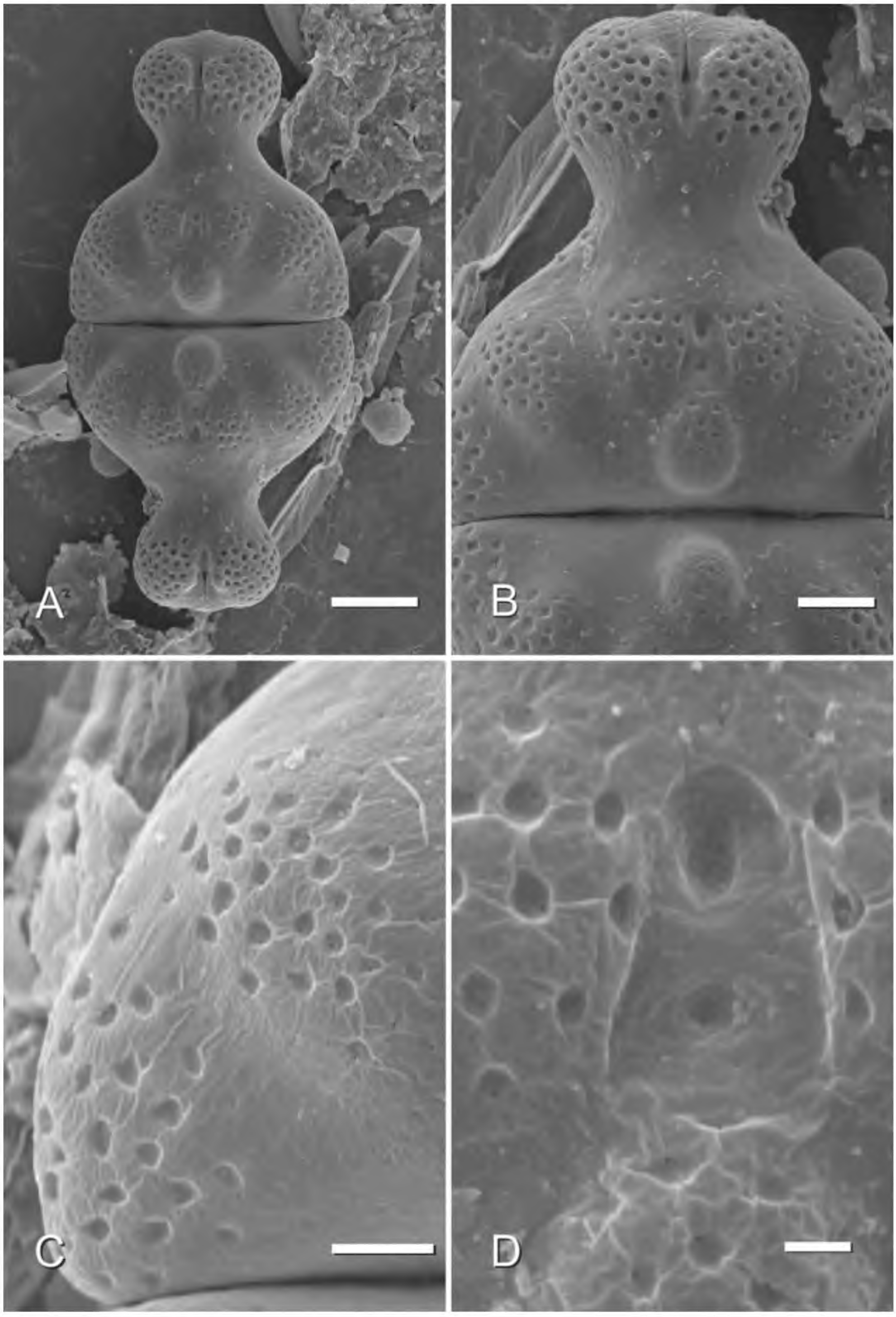

Fig. 32. Scanning electron micrographs of desmids, **A.** – **D.** *Euastrum* cf. *longicolle* var. *australicum*. Scale bar A = 20 µm; B = 10 µm; C = 5 µm; D = 2 µm.

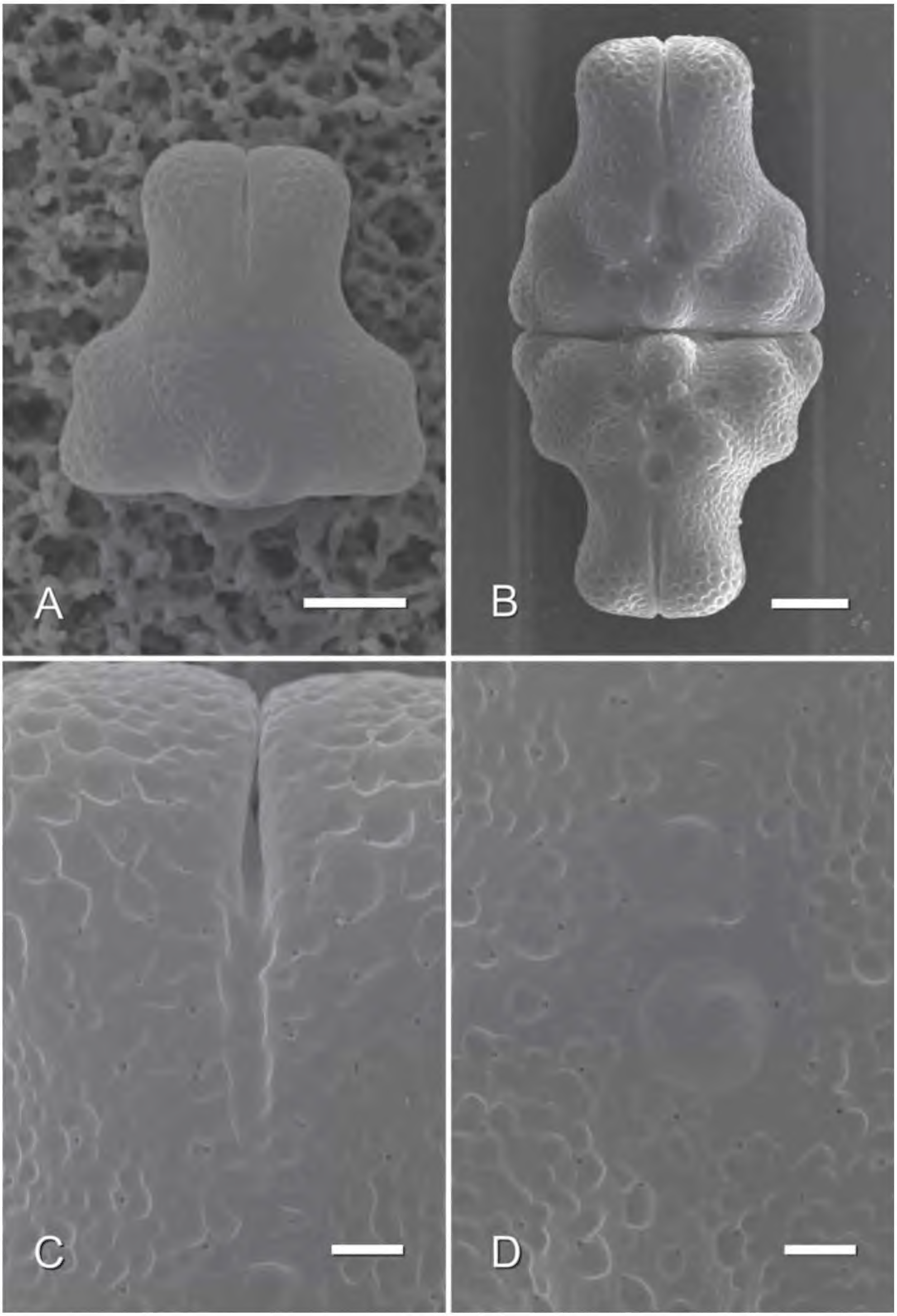

Fig. 33. Scanning electron micrographs of desmids, **A.** – **D.** *Euastrum sinuosum* var. *germanicum*. Scale bar A & B = 10 µm; C = 2 µm; D = 5 µm.

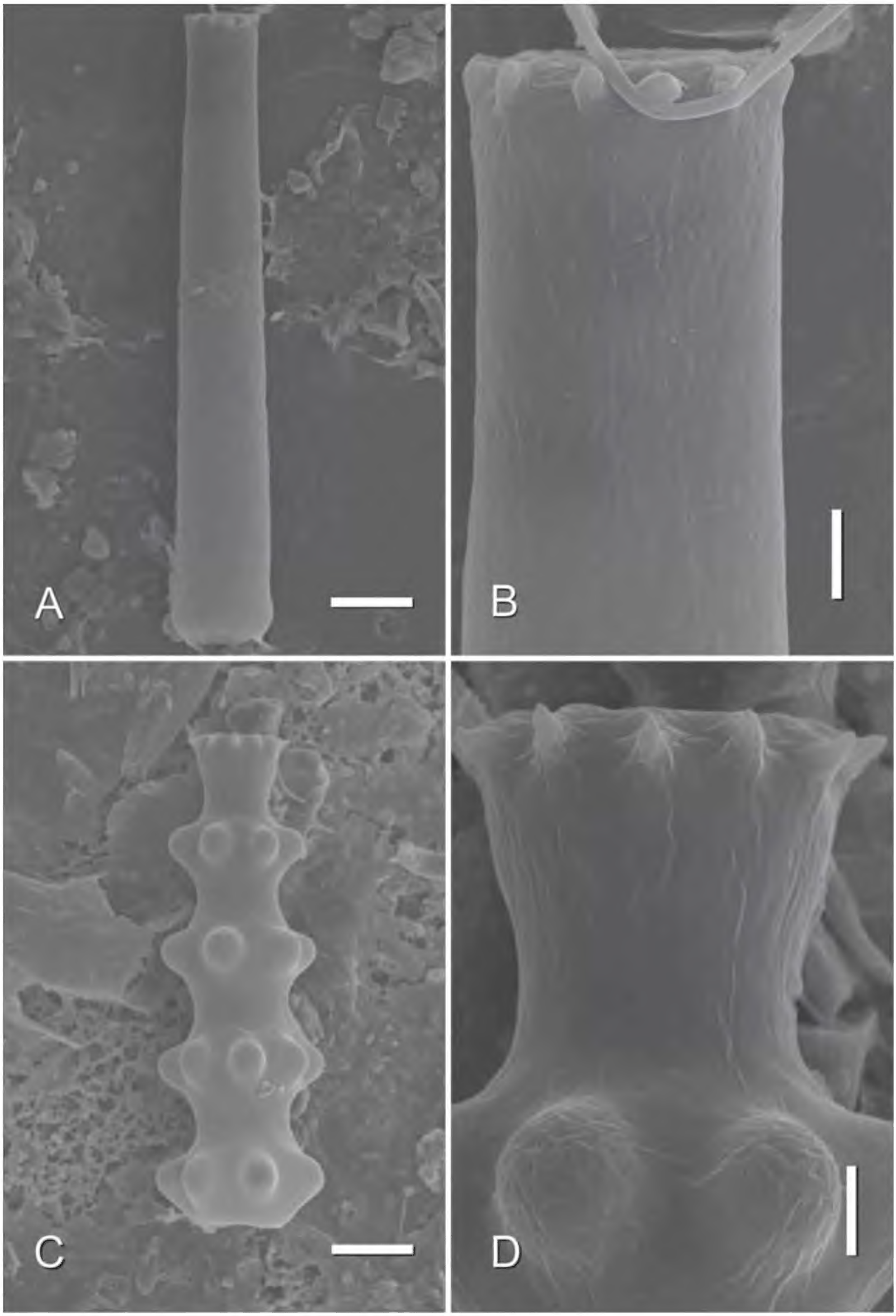

Fig. 34: Scanning electron micrographs of desmids, **A** & **B.** *Pleurotaenium ehrenbergii*. **C** & **D.** *P. nodosum*. Scale bar A & C = 20 μm; B & D = 5 μm.

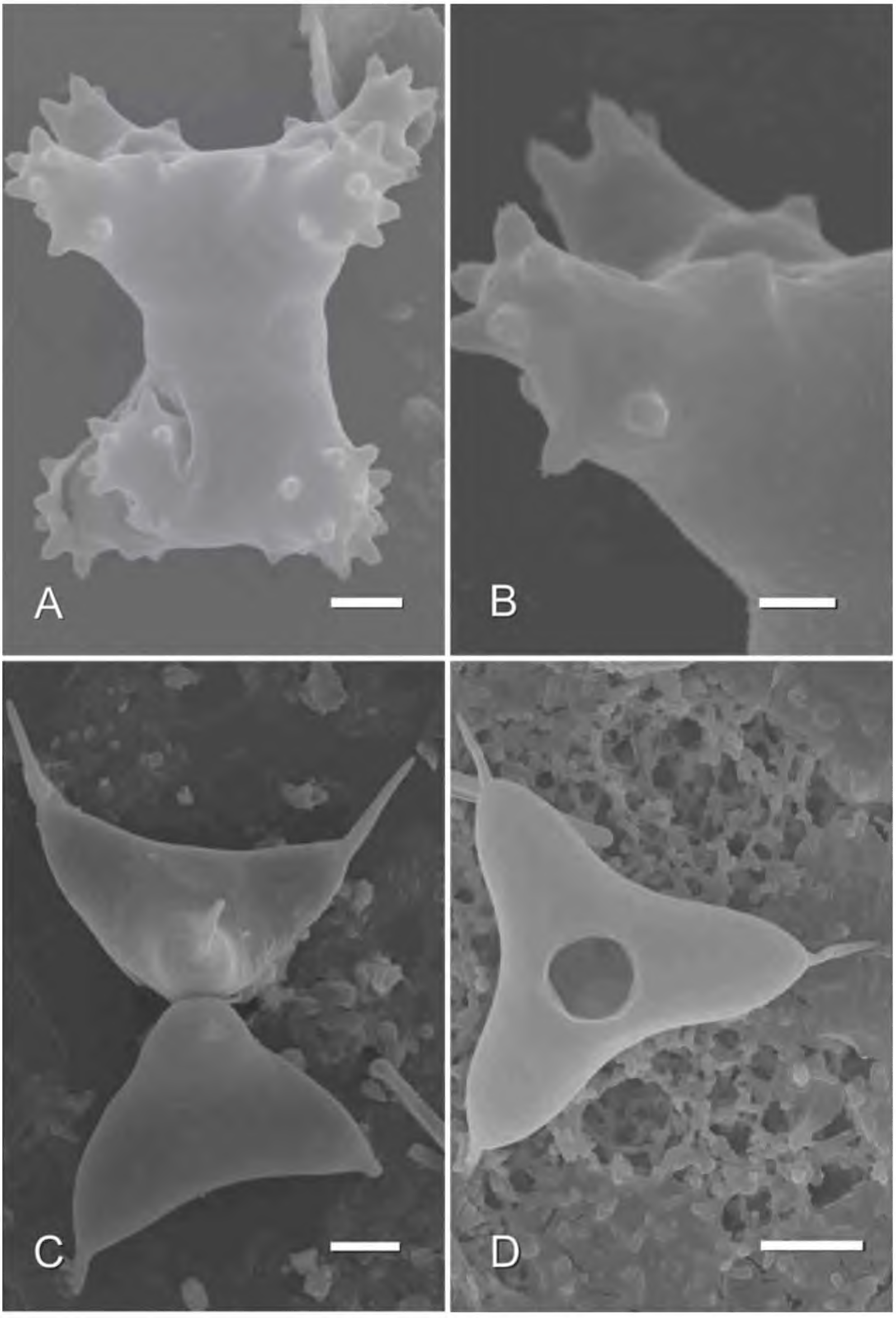

Fig. 35. Scanning electron micrographs of desmids, **A** & **B.** *Staurastrum inconspicuum*. **C.** *Staurodesmus* cf. *cuspidicurvatus* (F-stacked) & **D.** *S.* cf. *cuspidicurvatus.* Scale bar A = 2 µm; B = 1 µm; C = 5 µm; D = 10 µm.

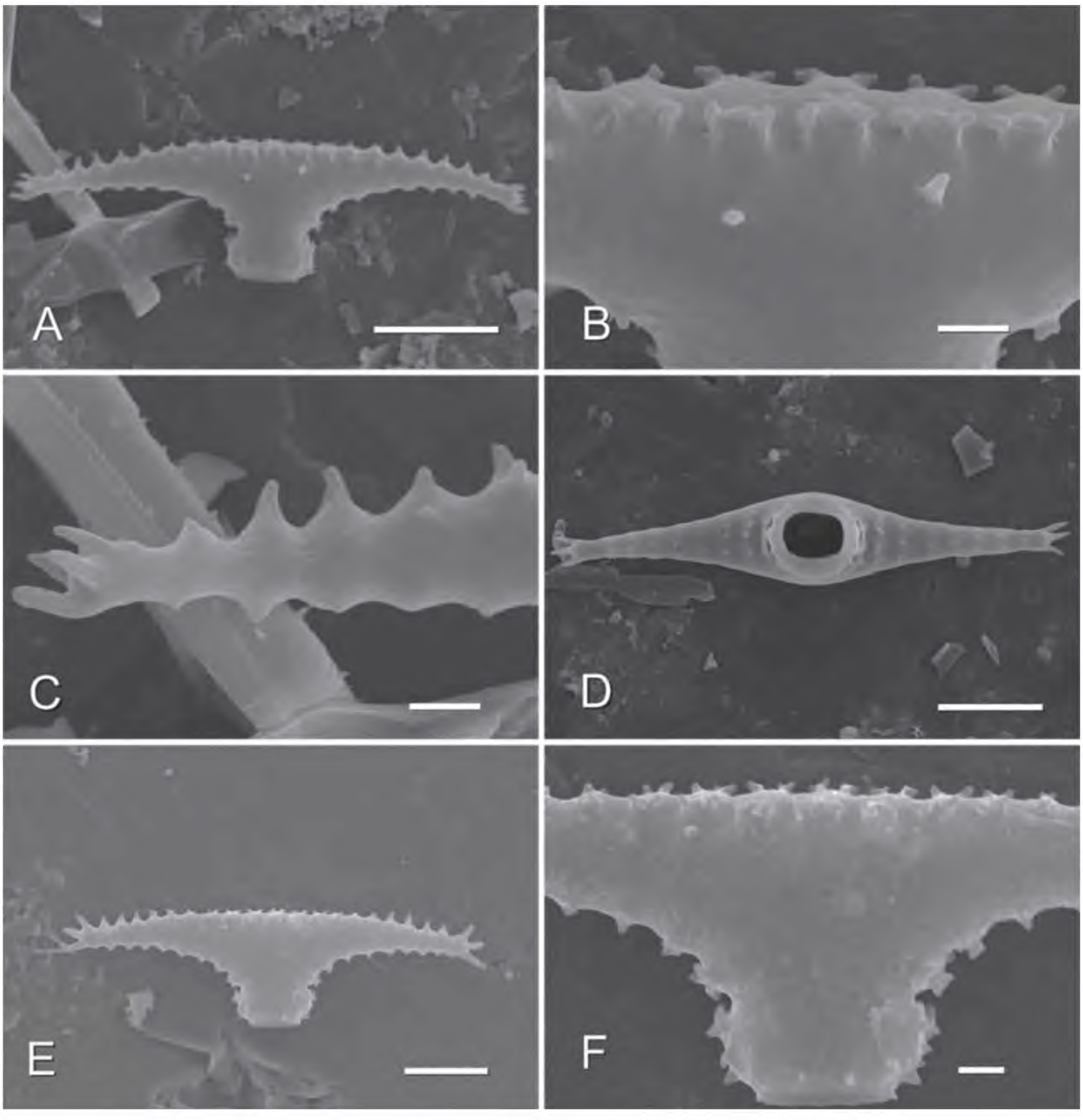

Fig. 36. Scanning electron micrographs of desmids, **A – F.** *Staurastrum* cf. *hardyi*. Scale bar A, D & E = 10 µm; B, C & F = 2 µm.

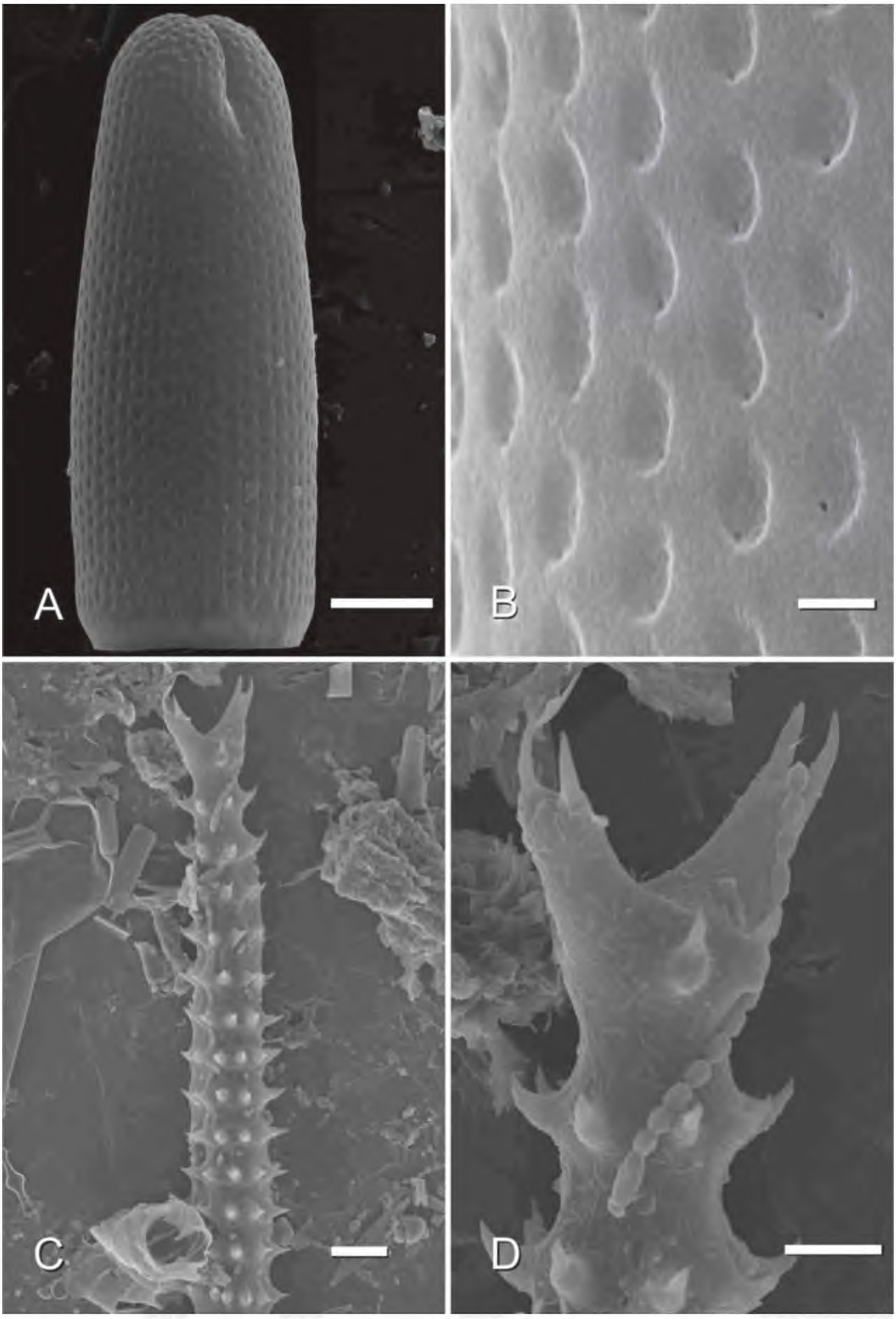

Fig. 37. Scanning electron micrographs of desmids, **A.** & **B.** *Tetmemorus brebissonii*. **C.** & **D.** *Triploceras gracile.* Scale bar A & D = 10 µm; B = 1 µm; C = 20 µm.

Conclusions

The present study recovered 80 *Sphagnum*-associated desmid taxa, which included two new species and several tentatively identified entities, highlighting the need for further taxonomic study of this group in Australia. Moreover, were the several taxa that were considered having a tenuous or dubious basis for varietal status. As alluded to previously, moving towards an integrated approach to determine species limits in Australian desmids would provide a more informed inventory of diversity.

The use of a NCV scheme allowed us to compare species diversity between Basket Swamp and Ebor Common and emphasise species of significance (bioindicators for rarity, ecosystem maturity, endemism and red list species) present at those sites. Results from the original and modified NCV were similar, suggesting their use in Australian wetland habitats is possible albeit that future work should address the limitations discussed herein.

Species associated with this substrate tended to be benthic and acidophilic, however, species with broader ecological ranges were also present, indicating migration from adjacent microhabitats had possibly occurred. Diversity between the studied sites was variable, with turnover prevailing over nestedness in terms of β-diversity patterns. Common desmid assemblages were also identified at a larger geographical scale from previous *Sphagnum* surveys from Australia and western Europe.

Additionally, local and regional endemics were recovered but require further study to confirm their ecological range like their better-known counterparts. These findings are of relevance for further biomonitoring studies concerned with the ecological status and conservation value of freshwater wetlands, especially for those habitats harbouring *Sphagnum* and its associated epiphyton.

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